U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-255 217

Technical Guidelines for Public Water Systems

Clean Water Consultants

Prepared For
Environmental Protection Agency

June 16, 1976

KEEP UP TO DATE

Between the time you ordered this report—which is only one of the hundreds of thousands in the NTIS information collection available to you—and the time you are reading this message, several *new* reports relevant to your interests probably have entered the collection.

Subscribe to the **Weekly Government Abstracts** series that will bring you summaries of new reports *as soon as they are received by NTIS* from the originators of the research. The WGA's are an NTIS weekly newsletter service covering the most recent research findings in 25 areas of industrial, technological, and sociological interest—invaluable information for executives and professionals who must keep up to date.

The executive and professional information service provided by NTIS in the **Weekly Government Abstracts** newsletters will give you thorough and comprehensive coverage of government-conducted or sponsored research activities. And you'll get this important information within two weeks of the time it's released by originating agencies.

WGA newsletters are computer produced and electronically photocomposed to slash the time gap between the release of a report and its availability. You can learn about technical innovations immediately—and use them in the most meaningful and productive ways possible for your organization. Please request NTIS-PR-205/PCW for more information.

The weekly newsletter series will keep you current. But *learn what you have missed in the past* by ordering a computer **NTISearch** of all the research reports in your area of interest, dating as far back as 1964, if you wish. Please request NTIS-PR-186/PCN for more information.

WRITE: Managing Editor
5285 Port Royal Road
Springfield, VA 22161

Keep Up To Date With SRIM

SRIM (Selected Research in Microfiche) provides you with regular, automatic distribution of the complete texts of NTIS research reports *only* in the subject areas you select. SRIM covers almost all Government research reports by subject area and/or the originating Federal or local government agency. You may subscribe by any category or subcategory of our WGA **(Weekly Government Abstracts)** or **Government Reports Announcements and Index** categories, or to the reports issued by a particular agency such as the Department of Defense, Federal Energy Administration, or Environmental Protection Agency. Other options that will give you greater selectivity are available on request.

The cost of SRIM service is only 45¢ domestic (60¢ foreign) for each complete microfiched report. Your SRIM service begins as soon as your order is received and processed and you will receive biweekly shipments thereafter. If you wish, your service will be backdated to furnish you microfiche of reports issued earlier.

Because of contractual arrangements with several Special Technology Groups, not all NTIS reports are distributed in the SRIM program. You will receive a notice in your microfiche shipments identifying the exceptionally priced reports not available through SRIM.

A deposit account with NTIS is required before this service can be initiated. If you have specific questions concerning this service, please call (703) 451-1558, or write NTIS, attention SRIM Product Manager.

This information product distributed by

NTIS U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

215210

PB 255 217

TECHNICAL GUIDELINES
FOR
PUBLIC WATER SYSTEMS

JUNE 1975

ENVIRONMENTAL PROTECTION AGENCY
WATER SUPPLY DIVISION
WASHINGTON, D.C. 20460

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

BIBLIOGRAPHIC DATA SHEET	1. Report No. None	2.	3. Recipient's Accession No.

4. Title and Subtitle

Technical Guidelines for Public Water Systems

5. Report Date
June 16, 1976

6.

7. Author(s)
Russell L. Culp

8. Performing Organization Rept. No. 46

9. Performing Organization Name and Address

Clean Water Consultants
P.O. Box 40
EL Dorado Hills, CA 95630

10. Project/Task/Work Unit No.
NA

11. Contract/Grant No.
68-01-2971

12. Sponsoring Organization Name and Address

Office of Water Supply (WH-550)
Environmental Protection Agency
Washington, D.C. 20460

13. Type of Report & Period Covered
Final

14.

15. Supplementary Notes
None

16. Abstracts

This report presents technical guidelines for the design, opreation, maintenance, staffing, and surveillance of public water systems including references and bibliography. Topics discussed include: general design considerations, source development, treatment, chemical application, pumping facilities, storage, distribution systems, operation and maintenance, surveillance, and personnel.

17. Key Words and Document Analysis. 17a. Descriptors

Water supply, water treatment, water distribution, water system operation and maintenance, water quality surveillance, water system personnel.

17b. Identifiers/Open-Ended Terms

Water supply, Water treatment

17c. COSATI Field/Group

PRICES SUBJECT TO CHANGE

18. Availability Statement Release Unlimited	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 474
	20. Security Class (This Page) UNCLASSIFIED	22. Price $12.00

FORM NTIS-35 (REV. 10-73) ENDORSED BY ANSI AND UNESCO. THIS FORM MAY BE REPRODUCED USCOMM-DC 8265-P74

EPA
June 1975

TECHNICAL GUIDELINES
FOR
PUBLIC WATER SYSTEMS

BY

Clean Water Consultants
Box 40, El Dorado Hills, Calif., 95630

Contract No. 68-01-2971

Project Officer
Thomas N. Hushower
Water Supply Division
U. S. Environmental Protection Agency
Washington, D. C. 20460

Prepared For

WATER SUPPLY DIVISION

U. S. ENVIRONMENTAL PROTECTION AGENCY

WASHINGTON, D. C. 20460

EPA Review Notice

This report has been reviewed by EPA, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

ACKNOWLEDGMENTS

Standards for water systems evolve from the accumulated experience in the field, particularly the experience with existing standards. In preparing this Manual the existing standards for water systems have been drawn on heavily for the material presented. This is recognized to some extent by the bibliography included and by the references in these Standards to such sources of information. However, it is appropriate to give further credit and recognition by special acknowledgment to some of the most frequently used materials. Section I, General Design Considerations; Section II, Source Development; Section III, Treatment; Section IV, Chemical Application; Section V, Pumping Facilities; Section VI, Storage; and Section VII, Distribution Systems are based for the most part on the "Recommended Standards for Water Works", by the Great Lakes - Upper Mississippi River Board of Sanitary Engineers, 1968 edition with 1972 addenda. Other State Standards were also used. The Standards, the Journal, and the Manuals of Practice of the American Water Works Association have been used extensively throughout preparation of all sections of this Manual. The EPA Manuals on Fluoridation, Cross-Connection Control, Evaluating Public Drinking Water Supplies, and other topics were helpful in many areas.

The Bibliography for this Manual lists more than 350 references which were used to varying degrees. Obviously it is not possible to refer directly to all of these sources without interfering with proper presentation and understanding of the text, but the usefulness of material drawn from unreferenced articles in the Bibliography is also hereby acknowledged.

CONTENTS

SECTION Page

INTRODUCTION i

I. General Design Considerations 1

Summary of Standards - General Design Considerations

1.1.0 Planning 1

1.2.0 Capacity and Sizing 1

1.3.0 Siting of Facilities 2

1.4.0 Plant and Building Design Parameters 3

1.5.0 Standby Power and Emergency Operations 4

1.6.0 Disposal of Plant Wastes 5

1.7.0 Use of New Processes or Equipment 6

Rationale for General Design Considerations

1.1.0 Planning 7

1.2.0 Capacity and Sizing 10

1.3.0 Siting of Facilities 13

1.4.0 Plant and Building Design Parameters 15

1.5.0 Standby Power and Emergency Operations 20

1.6.0 Disposal of Plant Wastes 21

1.7.0 Use of New Processes or Equipment 31

II. Source Development 33

2.1.0 General 33

Summary of Design Standards

2.2.0 Quantity and Quality 33

Preceding page blank

SECTION Page

2.2.1 Design Period for Surface Supply Works 33
2.2.2 Design Period for Ground Water Supplies 33
2.2.3 Quantity of Water From Surface Sources 33
2.2.4 Quantity of Water From Well Water Supplies 34
2.2.5 Safe Yield From Flowing Streams 34
2.2.6 Safe Yield for Reservoirs and Lakes 34
2.2.7 Safe Yield From Wells 34
2.2.8 Federal Drinking Water Standards 34
2.2.9 General Treatment Requirements 34
2.2.10 Bacteriological Quality Versus Treatment Requirements 36

  2.2.10.1 Low Coliform Waters 36
  2.2.10.2 Moderate Coliform Waters 36
  2.2.10.3 High Coliform Waters 37
  2.2.10.4 Excessively High Coliform Waters 37
  2.2.10.5 Wastewater Reuse 37

2.2.11 Chemical and Physical Quality Versus Treatment Requirements 38

  2.2.11.1 Maximum Contaminant Levels For Inorganic Chemicals 38
  2.2.11.2 Maximum Contaminant Levels For Organic Chemicals 39
  2.2.11.3 Maximum Contaminant Levels For Pesticides 39
  2.2.11.4 Maximum Contaminant Level For Turbidity 40
  2.2.11.5 Odor and Color 40
  2.2.11.6 Foaming Agents 40
  2.2.11.7 Iron and Manganese 40
  2.2.11.8 Copper, Zinc, and Hydrogen Sulfide 41
  2.2.11.9 Chlorides and Sulfates 41
  2.2.11.10 Sodium 41
  2.2.11.11 Radioactivity 41
  2.2.11.12 Asbestos 42

2.3.0 Surface Water 42

2.3.1 River Intakes 42

  2.3.1.1 Site Selection 42
  2.3.1.2 Sanitary Survey 42
  2.3.2.3 Preparation of Site 43
  2.3.2.4 Protection of Source 43

SECTION Page

2.3.2.5 Recreational Use Effects 43
2.3.2.6 Mixing or Aeration 43
2.3.2.7 Selection of Depth of Withdrawal 44
2.3.2.8 Evaporation, Seepage, and Siltation 44

2.3.3 Structures 44

2.3.3.1 Dams and Spillways 44
2.3.3.2 Intakes 44
2.3.3.3 Shore Wells 45
2.3.3.4 Off Channel Reservoirs 46
2.3.3.5 Raw Water Pumping Stations 46

2.4.0 Ground Water 46

2.4.1 Sources of Groundwater 46
2.4.2 Location and Protection 46

2.4.2.1 Sewers and Septic Tanks 46
2.4.2.2 Sanitary Survey 47

2.4.3 Infiltration Galleries 48
2.4.4 Springs 50
2.4.5 Wells 51

2.4.5.1 Minimum Protective Depths 51
2.4.5.2 Required Special Protection for Various Sources 51
2.4.5.3 General Well Construction Requirements 53
2.4.5.4 Bacteriological Quality Testing 57
2.4.5.5 Chemical Quality Testing 57
2.4.5.6 Water Level Measurement 58
2.4.5.7 Observation Wells 58
2.4.5.8 Well Abondonment 58
2.4.5.9 Pitless Units for Public Water Supply Wells 58
2.4.5.10 Duplicate Installations Required 59

Rationale for Source Development Standards 61

2.2.0 Quantity and Quality 61

2.2.1 Design Period for Surface Supply Works 62
2.2.2 Design Period for Ground Water Supplies 62
2.2.3 Quantity of Water From Surface Sources 63
2.2.4 Quantity of Water From Well Water Supplies 63
2.2.5 Safe Yield From Flowing Streams 63
2.2.6 Safe Yield For Reservoirs and Lakes 64

SECTION Page

2.2.7 Safe Yield From Wells 64
2.2.8 Federal Drinking Water Standards 65
2.2.9 General Treatment Requirements 65
2.2.10 Bacteriological Quality Versus Treatment Requirements 65
2.2.11 Chemical and Physical Quality Versus Treatment Requirements 66

2.2.11.1 Inorganic Chemicals 66
2.2.11.2 Organic Chemicals 68
2.2.11.3 Pesticides 68
2.2.11.4 Turbidity 68
2.2.11.5 Odor and Color 68
2.2.11.6 Foaming Agents 68
2.2.11.7 Iron and Manganese 68
2.2.11.8 Copper, Zinc, and Hydrogen Sulfide 69
2.2.11.9 Chlorides and Sulfates 69
2.2.11.10 Sodium 69
2.2.11.11 Radioactivity 69
2.2.11.12 Asbestos 74

2.3.0 Surface Water 76

2.3.1 River Intakes 76
2.3.2 Impoundments 77

2.3.2.1 Site Selection 77
2.3.2.2 Sanitary Survey
2.3.2.3 Preparation of Site 81
2.3.2.4 Protection of Source 82
2.3.2.5 Recreational Use Effects 83
2.3.2.6 Mixing or Aeration 83
2.3.2.7 Selection of Depth of Withdrawal 83
2.3.2.8 Evaporation, Seepage, and Siltation 84

2.3.3 Structures

2.3.3.1 Dams and Spillways 84
2.3.3.2 Intakes 84

2.4.0 Ground Water 85

2.4.2 Location and Protection 85
2.4.3 Infiltration Galleries 86
2.4.4 Springs 86
2.4.5 Wells 87

2.4.5.1 Minimum Protective Depths 87
2.4.5.2 Required Special Protection for Various Sources 88

SECTION Page

2.4.5.3 General Well Construction Requirements 88
2.4.5.4 Bacteriological Quality Testing 89
2.4.5.5 Chemical Quality Testing 89
2.4.5.6 Water Level Management 89
2.4.5.7 Observation Wells 89
2.4.5.8 Well Abandonment 90
2.4.5.9 Pitless Units for Public Water Supply Wells 90
2.4.5.10 Duplicate Installations Required 90

III. Treatment 91

Summary of Treatment Standards

3.1.0 Clarification 91

3.1.1 Presedimentation 91
3.1.2 Mixing (Flash or Quick) 92
3.1.3 Flocculation (Slow Mixing) Basins, Primary or Secondary 92
3.1.4 Sedimentation 93
3.1.5 Solids Contact Units 94

3.1.5.1 Installation of Equipment 94
3.1.5.2 Operating Equipment 94
3.1.5.3 Chemical Feed 95
3.1.5.4 Mixing 95
3.1.5.5 Flocculation 95
3.1.5.6 Sludge Concentrators 95
3.1.5.7 Sludge Removal 95
3.1.5.8 Cross-Connections 95
3.1.5.9 Detention Period 96
3.1.5.10 Suspended Slurry Concentrate 96
3.1.5.11 Water Losses 96
3.1.5.12 Weirs or Orifices 96
3.1.5.13 Weir Loading 96
3.1.5.14 Upflow Rates 97

3.1.6 Settling Tube Clarifiers 97

3.1.6.1 Settling Tube Installations in Horizontal Flow Basins, Loading Rates 97
3.1.6.2 Settling Tube Installations 98
3.1.6.3 Location of Tube Modules Within Basin 98
3.1.6.4 Tube Support Requirements 98
3.1.6.5 Tube Cleaning 98

SECTION Page

3.2.0 Filtration 98

3.2.1 Rapid Gravity Filters 99

3.2.1.1 Pretreatment 99
3.2.1.2 Number 99
3.2.1.3 Rate of Filtration 99
3.2.1.4 Structural Details and Hydraulics 99
3.2.1.5 Washwater Troughs 100
3.2.1.6 Filter Material 100
3.2.1.7 Restricted Declining Flow Rate Filters 103
3.2.1.8 Filter Bottom and Strainer Systems 103
3.2.1.9 Surface Wash 104
3.2.1.10 Appurtenances 104
3.2.1.11 Backwash 105

3.2.2 Rapid Sand Pressure 105

3.2.2.1 General 105
3.2.2.2 Rate of Filtration 105
3.2.2.3 Details of Design 106

3.2.3 Slow Rate Gravity Filters 106

3.2.3.1 Quality of Raw Water 107
3.2.3.2 Structural Details and Hydraulics 107
3.2.3.3 Rates of Filtration 107
3.2.3.4 Underdrains 107
3.2.3.5 Filtering Material 107
3.2.3.6 Filter Gravel 108
3.2.3.7 Depth of Water on Filter Beds 108
3.2.3.8 Control of Appurtenances 108

3.2.4 Diatomaceous Earth Filtration 108
3.2.5 Granular Carbon Filter Material 109

3.3.0 Disinfection 109

3.3.1 Chlorination Equipment 110

3.3.1.1 Type 110
3.3.1.2 Capacity 110
3.3.1.3 Standby Equipment 110
3.3.1.4 Automatic Proportioning 110
3.3.1.5 Contact Time and Point of Application 110
3.3.1.6 Residual Testing Equipment 110
3.3.1.7 Housing 111

SECTION Page

3.3.2 Ozonation Equipment 111

- 3.3.2.1 Type 111
- 3.3.2.2 Capacity 111
- 3.3.2.3 Standby Equipment 111
- 3.3.2.4 Automatic Proportioning 111
- 3.3.2.5 Application 111
- 3.3.2.6 Contact Time and Point of Application 111
- 3.3.2.7 Residual Testing Equipment 112
- 3.3.2.8 Ozonator Piping 112
- 3.3.2.9 Housing 112
- 3.3.2.10 Residual 112

3.3.3 Ultraviolet Radiation 112

3.4.0 Softening 112

3.4.1 Lime-Soda 113

- 3.4.1.1 Equipment 113
- 3.4.1.2 Aeration 113
- 3.4.1.3 Stabilization 113
- 3.4.1.4 Sludge Disposal 113
- 3.4.1.5 Disinfection 113

3.4.2 Cation Exchange Process 113

- 3.4.2.1 Design 113
- 3.4.2.2 Exchange Capacity 113
- 3.4.2.3 Depth Of Media 113
- 3.4.2.4 Flow Rates 113
- 3.4.2.5 Freeboard 114
- 3.4.2.6 Underdrains and Supporting Gravel 114
- 3.4.2.7 Brine Distribution 114
- 3.4.2.8 Bypass 114
- 3.4.2.9 Additional Limitations 114
- 3.4.2.10 Sampling Taps 114
- 3.4.2.11 Brine and Salt Storage Tanks 114
- 3.4.2.12 Storage Capacity 115
- 3.4.2.13 Stabilization 115
- 3.4.2.14 Waste Disposal 115
- 3.4.1.15 Construction Material 115
- 3.4.2.16 Housing 115

3.5.0 Aeration 115

- 3.5.1 Natural Draft Aeration 115
- 3.5.2 Forced or Induced Draft Aeration 116

SECTION Page

3.5.3 Pressure Aeration 116
3.5.4 Other Methods of Aeration 116
3.5.5 Protection From Wind 116
3.5.6 Protection From Contamination 116
3.5.7 Bypass 116

3.6.0 Iron and Manganese Control 116

3.6.1 Removal by Oxidation, Detention, and Filtration 117

3.6.1.1 Oxidation 117
3.6.1.2 Detention 117
3.6.1.3 Filtration 117

3.6.2 Removal by Lime-Soda Process 117
3.6.3 Removal by Units Using Continuous Potassium Permanganate "Regeneration" 117
3.6.4 Removal by Ion Exchange 118
3.6.5 Sequestration 118
3.6.6 Sampling Equipment 118
3.6.7 Testing Equipment 118

3.7.0 Fluoridation and Defluoridation 118

3.7.1 Fluoride Compound Storage 119
3.7.2 Dry Conveyors 119
3.7.3 Chemical Feed Installations 119
3.7.4 Protective Equipment 119
3.7.5 Dust Control Equipment 119
3.7.6 Testing Equipment 119
3.7.7 Defluoridation 119

3.8.0 Stabilization 119

3.8.1 Carbon Dioxide Addition 120
3.8.2 Sulfuric Acid 120
3.8.3 Polyphosphates 120
3.8.4 "Split Treatment" 121
3.8.5 Alkali Feed 121
3.8.6 Carbon Dioxide Reduction by Aeration 121
3.8.7 Other Treatment 121
3.8.8 Water Unstable Due to Action in Distribution System 121
3.8.9 Control 121

3.9.0 Taste and Odor Control 121

3.9.1 Chlorine and Chlorine Dioxide 121
3.9.2 Powdered Activated Carbon 122
3.9.3 Granular Activated Carbon Adsorption Units 122

SECTION Page

3.9.4 Copper Sulfate and Other Copper Compounds 122
3.9.5 Potassium Permanganate 122
3.9.6 Other Methods 122
3.9.7 Flexibility 122

3.10.0 Microscreening 123

3.10.1 Design 123

3.11.0 Waste Disposal 123

3.12.0 Salt Removal 123

3.12.1 Ion Exchange 123
3.12.2 Reverse Osmosis 124
3.12.3 Electrodialysis 124

3.13.0 Organics Removal by Activated Carbon Adsorbtion 124

3.13.1 Adsorption of Organics on Granular Activated Carbon 125
3.13.2 Granular Carbon Specifications 125
3.13.3 Contact Time 126
3.13.4 Carbon Bed or Column Design 126
3.13.5 Carbon Regeneration 127

3.14.0 Activated Carbon for Dechlorination of Waters 128

Rationale for Treatment Standards 129

3.1.0 Clarification 129

3.1.1 Presedimentation 129
3.1.2 Mixing 129
3.1.3 Flocculation (Slow Mixing) Basins, Primary or Secondary 130
3.1.4 Sedimentation 131
3.1.5 Solids Contact Units 132
3.1.6 Settling Tube Clarifiers 133

3.2.0 Filtration 133

3.2.1 Rapid Growth Filters 134

3.2.1.1 Pretreatment 134
3.2.1.2 Number 134

SECTION Page

3.2.1.3 Rate of Filtration 135
3.2.1.4 Structural Details and Hydraulics 135
3.2.1.5 Washwater Troughs 136
3.2.1.6 Filter Material 136
3.2.1.8 Filter Bottoms and Strainer Systems 136
3.2.1.9 Surface Wash 137
3.2.1.10 Appurtenances 138
3.2.1.11 Backwash 139

3.2.2 Rapid Pressure Filters 141
3.2.3 Slow Rate Gravity Filters 142
3.2.4 Diatomaceous Earth Filtration 142
3.2.5 Granular Carbon Filter Material 143

3.3.0 Disinfection 143

3.4.0 Softening 145

3.5.0 Aeration 145

3.6.0 Iron and Manganese Control 146

3.7.0 Fluoridation 147

3.8.0 Stabilization 147

3.9.0 Taste and Odor Control 148

3.10.0 Microscreening 148

3.11.0 Waste Disposal 149

3.12.0 Salt Removal 149

3.13.0 Organics Removal by Granular Carbon Adsorption 150

3.13.1 Adsorption of Organics on Granular Activated Carbon 150
3.13.2 Granular Carbon Specifications 151
3.13.3 and 3.13.4 Contact Time and Carbon Bed or Column Design 152
3.13.5 Carbon Regeneration 153

3.14.0 Activated Carbon for Dechlorination 155

IV Chemical Application 157

Summary of Standards for Chemical Application 157

SECTION Page

4.0.0 General 157

4.0.1 Approval of Plans and Specifications 157
4.0.2 Chemical Application Points 157

4.1.0 Feed Equipment 158

4.1.1 Number of Feeders 158
4.1.2 Design and Capacity 158
4.1.3 Location 159
4.1.4 Control 159
4.1.5 Solution Tanks 160
4.1.6 Weighing Scales 161
4.1.7 Feed Lines 161
4.1.8 Service Water Supply 162

4.2.0 Chemicals 162

4.2.1 Quality 162
4.2.2 Storage 163
4.2.3 Handling 164

4.3.0 Housing 165

4.4.0 Operator Safety 166

4.5.0 Hazardous Material Handling and Spills 167

Rationale for Chemical Application Standards 169

4.1.0 Feed Equipment 169

4.1.1 Number of Feeders 169
4.1.2 Design and Capacity 169
4.1.3 Location 169
4.1.4 Control 169
4.1.5 Solution Tanks 170
4.1.6 Weighing Scales 170
4.1.7 Feed Lines 170
4.1.8 Service Water Supply 170

4.2.0 Chemicals 170

4.2.1 Quality 170
4.2.2 Storage 171
4.2.3 Handling 171

4.3.0 Housing 171

4.4.0 Operator Safety 171

4.5.0 Hazardous Material Handling and Spills 171

SECTION Page

V Pumping Facilities 173

Summary of Standards - Pumping Facilities 173

5.0.0 General 173

5.1.0 Location 173

5.1.1 Site Protection 173
5.1.2 Selection 173

5.2.0 Ground Water Facilities 173

5.2.1 Sanitary Protection 174

5.2.1.1 Dug Wells 174
5.2.1.2 Driven or Drilled Wells 174
5.2.1.3 Submersible Pumps 174
5.2.1.4 Discharge Piping 174

5.2.2 Well Construction 175

5.2.3 Well Pumps 175

5.2.3.1 Certified Pumps 175
5.2.3.2 Jet Pumps 176
5.2.3.3 Air Lift Pumps 176
5.2.3.4 Rotary Pumps 176
5.2.3.5 Reciprocating Pumps 176
5.2.3.6 Desirable Operating Conditions 176
5.2.3.7 Power Requirements 177
5.2.3.8 Drives 177
5.2.3.9 Pump Selection and Installation 177
5.2.3.10 Pump Testing 177

5.3.0 Surface Water Facilities 178

5.3.1 Suction Well 178
5.3.2 Equipment Servicing 178
5.3.3 Stairways and Ladders 178
5.3.4 Heating 179
5.3.5 Ventilation 179
5.3.6 Dehumidification 179
5.3.7 Lighting 179
5.3.8 Sanitary and Other Conveniences 179
5.3.9 Pumps 179
5.3.10 Suction Lift 180
5.3.11 Priming 180

SECTION Page

5.4.0 Booster Pumps 180

  5.4.1 Inline Booster Pumps 180

5.5.0 Selection of Pumps for Surface Water Facilities and Booster Service 181

  5.5.1 Pump Types 181
  5.5.2 Booster Pumps 181
  5.5.3 Pump Selection 181

    5.5.3.1 Capacity 181
    5.5.3.2 Characteristic Curves 181
    5.5.3.3 Efficiency 182
    5.5.3.4 Power Input 182
    5.5.3.5 Speed 182
    5.5.3.6 Space Requirements 183
    5.5.3.7 Operating Flexibility 183

5.6.0 Automatic and Remote Controlled Stations 184

5.7.0 Appurtenances 184

  5.7.1 Valves 184
  5.7.2 Piping 185
  5.7.3 Gauges and Meters 185
  5.7.4 Water Seals 186
  5.7.5 Controls 186
  5.7.6 Power 186
  5.7.7 Auxiliary Power Supply 186

Rationale for Standards for Pumping Facilities 187

5.1.0 General 187

  5.1.1 Location 187

5.2.0 Ground Water Facilities 187

  5.2.1 Sanitary Protection 187
  5.2.2 Well Construction 187
  5.2.3 Well Pumps 187

    5.2.3.1 Certified Pumps 187
    5.2.3.2 Desirable Operating Conditions 188
    5.2.3.3 Drives 188
    5.2.3.4 Power Requirements 188
    5.2.3.5 Pump Selection and Installation 188

SECTION Pump

5.3.0 Surface Water Facilities 192

5.3.1 Suction Well 192
5.3.2 Equipment Servicing 192
5.3.3 Stairways and Ladders 193
5.3.4 Heating 193
5.3.5 Ventilation 193
5.3.6 Dehumidification 193
5.3.7 Lighting 193
5.3.8 Sanitary and Other Conveniences 193
5.3.9 Pumps 193
5.3.10 and 5.3.11 Suction Lift and Priming 193

5.4.0 Booster Pumps 194

5.5.0 Selection of Pumps for Surface Water Facilities and Booster Service 194

5.6.0 Automatic and Remote Controlled Stations 194

5.7.0 Appurtenances 194

VI. STORAGE 195

Summary of Standards for Finished Water Storage 195

6.0.0 General 195

6.1.0 Selection of Type & Location of Storage 195

6.1.1 Type 195
6.1.2 Location 196

6.2.0 Protection 196

6.2.1 Covers and Roofs 196
6.2.2 Protection From Trespassers 196
6.2.3 Drains 196
6.2.4 Overflow 196
6.2.5 Access 197
6.2.6 Vents 197
6.2.7 Roof and Sidewall 198
6.2.8 Drainage for Roof or Cover 198
6.2.9 Safety 198
6.2.10 Freezing 199
6.2.11 Internal Catwalk 199
6.2.12 Grading 199
6.2.13 Painting and/or Cathodic Protection 199
6.2.14 Silt Protection 199
6.2.15 Fire Protection 199

6.3.0 Materials 199

SECTION Page

6.3.1 Steel 199
6.3.2 Concrete 200

6.4.0 Disinfection 200

6.5.0 Plant Storage 200

6.5.1 Washwater Tanks 200
6.5.2 Clearwell 200
6.5.3 Adjacent Compartments 201
6.5.4 Basin and Wet Wells 201
6.5.5 Pressure Tanks 201

6.6.0 Distribution Storage 202

6.6.1 Capacity 202
6.6.2 Pressure Variation 202
6.6.3 Drainage 202
6.6.4 Level Controls 202
6.6.5 Miscellaneous Design Considerations 203

Rationale for Storage Standards 205

6.0.0 General 205

6.1.0 Selection of Type and Location of Storage 205

6.1.1 Type 205
6.1.2 Location 205

6.2.0 Protection 206

6.2.1 Covers and Roofs 206
6.2.2 through 6.2.12 206
6.2.13 Painting and/or Cathodic Protection 206
6.2.14 Silt Protection 207
6.2.15 Fire Protection 207

6.3.0 Materials 207

6.4.0 Disinfection 207

6.5.0 Plant Storage 207

6.5.1 Washwater Tanks 207
6.5.2 Clearwell 207
6.5.3 Adjacent Compartments 208
6.5.4 Basin and Wet Wells 208
6.5.5 Pressure Tanks 208

6.6.0 Distribution Storage 208

SECTION Page

6.6.5 Miscellaneous Design Considerations 208

VII. DISTRIBUTION SYSTEM 209

Summary of Standards for Distribution Systems 209

7.1.0 General Protection Principles 209

7.1.1 Quantity and Pressure 209
7.1.2 Quality 209
7.1.3 Quality Sampling 209
7.1.4 Valves 209
7.1.5 Disinfection 209
7.1.6 Cross-Connections 210
7.1.7 Leakage 210
7.1.8 Submarine Lines 210
7.1.9 Repairs, Replacements, and Extension of Mains 210

7.2.0 Pipeline Location and Protection 210

7.2.1 Location 210

7.2.1.0 General Location Considerations 210
7.2.1.1 Separation of Water Mains & Sewers 211
7.2.1.2 Drains 212
7.2.1.3 Trench Flooding 212
7.2.1.4 Frost 212
7.2.1.5 Dead Ends 213

7.2.2 Protection 213

7.2.2.1 Pressure 213
7.2.2.2 Caulking Materials 213
7.2.2.3 Line Deposits 213
7.2.2.4 Corrosion 213
7.2.2.5 Corrosion Control 214
7.2.2.6 Surface Water Crossings 214
7.2.2.7 Plastic Pipe 215
7.2.2.8 Sanitary Precautions 215
7.2.2.9 Leakage 215
7.2.2.10 Disinfection 215
7.2.2.11 Bacteriological Examination 215
7.2.2.12 Thrust Blocks 215

7.3.0 Materials and Installation 216

7.3.1 Distribution Systems 216

7.3.1.1 Used Pipe 218
7.3.1.2 Packing and Jointing Material 218

SECTION Page

7.3.1.3 Minimum Pipe Size 218
7.3.1.4 Valve, Air Relief, and Blow-Off Chambers 219
7.3.1.5 Fire Hydrants 219
7.3.1.6 Installation of Mains 220
7.3.1.7 Water Pressure in System 220

7.3.2 Water Services & Plumbing 220
7.3.3 Cross-Connections 220

7.4.0 System Design 222

7.4.1 Field Studies of Distribution Systems 222
7.4.2 Office Studies of Distribution Systems 222
7.4.3 Main Size and Spacing 222
7.4.4 Valve Spacing 222
7.4.5 Valve Sizing 223
7.4.6 Valve Location 223
7.4.7 Metering 224

Rationale for Distribution System Standards 225

7.1.0 General Protection Principles 225

7.1.1 Quantity and Pressure 226
7.1.2 Quality 226
7.1.3 Quality Sampling 226
7.1.4 Valves 226
7.1.5 Disinfection 226
7.1.6 Cross-Connections 227
7.1.7 Leakage 227
7.1.8 Submarine Lines 227
7.1.9 Repairs, Replacements, and Extension of Mains 227

7.2.0 Pipeline Location and Protection 227

7.2.1 Location 227

7.2.1.1 Separation of Water Mains & Sewers 227
7.2.1.2 Drains 227
7.2.1.3 Trench Flooding 228
7.2.1.4 Frost 228
7.2.1.5 Dead Ends 228

7.2.2 Protection 228

7.2.2.1 Pressure 228
7.2.2.2 Caulking Materials 228
7.2.2.3 Line Deposits 228
7.2.2.4 Corrosion of Service Lines 228

SECTION Page

7.2.2.5 Corrosion Control 228
7.2.2.6 Surface Water Crossings 229
7.2.2.7 Plastic Pipe 229
7.2.2.8 Sanitary Precautions 229
7.2.2.9 Leakage 229
7.2.2.10 Disinfection 229
7.2.2.11 Bacteriological Examination 229

7.3.0 Materials and Installation 229

7.3.1 Distribution Standards 229

7.3.1.1 Used Pipe 230
7.3.1.2 Packing and Jointing Materials 230
7.3.1.3 Minimum Pipe Size 230
7.3.1.4 Valve, Air Relief, and Blow-Off Chambers 230
7.3.1.5 Fire Hydrants 231
7.3.1.6 Installation of Mains 231
7.3.1.7 Water Pressure in System 233

7.3.2 Water Services & Plumbing 234
7.3.3 Cross-Connections 235

7.4.0 System Design 235

7.4.1 Field Studies of Distribution Systems 235
7.4.2 Office Studies of Distribution Systems 235
7.4.3 Main Size and Spacing 235
7.4.4 Valve Spacing 235
7.4.5 Valve Sizing 235
7.4.6 Valve Locations 235
7.4.7 Metering 235

VIII. OPERATION AND MAINTENANCE 237

Summary of Standards for Operation and Maintenance 237

8.1.0 Operation and Maintenance 237

8.1.1 Supervision 237

8.1.1.1 Number and Types of Staff 237
8.1.1.2 Delegation of Responsibility 237
8.1.1.3 Federal and State Inspections 237

8.1.2 Analyses and Records 239

8.1.2.1 Annual Summary 239

8.1.3 Public Notification of Variances, Exemptions, and Noncompliance With EPA, IPS 240

SECTION Page

8.1.4 Water Utility Action Required for Noncompliance With EPA, IPS 241
8.1.5 Operation and Maintenance Manual 241

8.1.5.1 Operator Training 242

8.1.6 Operating Well Pumps 242
8.1.7 Pump Operation Checks 242
8.1.8 Basin Operations 243
8.1.9 Operation of Chemical Feeders 243
8.1.10 Filter Operation 243
8.1.11 Operation of Finished Water Tanks & Reservoirs 244
8.1.12 Operation of Distribution Systems 244

8.1.12.1 Main Disinfection 245
8.1.12.2 Pipe Joints 245
8.1.12.3 Negative Pressure 245
8.1.12.4 Cross-Connection Control 245

8.1.13 Treatment Chemicals and Other Supplies 245
8.1.14 Maintenance Program 245

8.1.14.1 Plant Grounds 246
8.1.14.2 Raw Water Reservoirs 246
8.1.14.3 Buildings 247
8.1.14.4 Basins and Clearwells 247
8.1.14.5 Chlorinator Room 247
8.1.14.6 Pumps and Well Houses 247
8.1.14.7 Pumps and Equipment 247
8.1.14.8 Pipelines 248
8.1.14.9 Storage Tanks 248

8.2.0 Budgeting and Financial Planning 248

8.2.1 Long Range Financial Planning 248
8.2.2 Sources of Income 248
8.2.3 Expenses 249
8.2.4 Accounting and Budgeting 249

8.3.0 Customer Relations 250

8.3.1 Management 250
8.3.2 Setting the Objective 250
8.3.3 Internal Action 250

8.3.3.1 Review of Existing Policies 251
8.3.3.2 Establishing New Policy 251

8.3.4 External Action 251

SECTION Pa e

8.4.0 Emergency Plans of Action 251

8.4.1 Desirable Scope 251
8.4.2 Disaster Effects 252
8.4.3 Vulnerability Assessment 252
8.4.4 Protective Measures 253
8.4.5 Emergency Operations Planning 253
8.4.6 Making & Implementing an Emergency Operations Plan 254
8.4.7 Security 254

Rationale for Operation and Maintenance Standards 255

8.1.0 Operation and Maintenance Program 255

8.1.1 Supervision 255

8.1.1.1 Number and Types of Staff 255
8.1.1.2 Delegation of Responsibility 255

8.1.2 Analyses and Records 255

8.1.2.1 Annual Summary 256

8.1.3 Public Notification of Variances, Exemptions, or Nonconformance With EPA, IPS 256
8.1.4 Water Utility Action Required for Noncompliance With EPA, IPS 256
8.1.5 Operating Practice Manual 256

8.1.5.1 Operator Training 256

8.1.6 Operating Well Pumps 256
8.1.7 Pump Operation Checks 257
8.1.8 Basin Operations 257
8.1.9 Operation of Chemical Feeders 257
8.1.10 Filter Operation 257
8.1.11 Operation of Finished Water Tanks and Reservoirs 261
8.1.12 Operation of Distribution Systems 261

8.1.12.1 Main Disinfection 261
8.1.12.2 Pipe Joints 262
8.1.12.3 Negative Pressure 262
8.1.12.4 Cross-Connection Control 262

8.1.13 Treatment Chemicals and Other Supplies 262
8.1.14 Maintenance Program 262

8.1.14.1 through 8.1.14.9 262

SECTION Page

8.2.0 Budgeting and Financial Planning 262

8.3.0 Customer Relations 262

8.4.0 Emergency Plans of Action 263

IX SURVEILLANCE 265

Summary of Surveillance Standards 265

9.1.0 Surveillance 265

9.2.0 Responsibility 265

9.3.0 Source and Facilities Surveillance 265

- 9.3.1 Reliability of System 265
- 9.3.2 Source 266
  - 9.3.2.1 Surveys 266
- 9.3.3 Treatment 266
- 9.3.4 Water Supply Systems 266
- 9.3.5 Other Requirements 267

9.4.0 Sampling Frequency 267

- 9.4.1 Microbiological Contaminant Sampling and Analytical Requirements 267
  - 9.4.1.1 Substitution of Residual Chlorine Measurement for Total Coliform Measurement 270
  - 9.4.1.2 Laboratory Certification 271
- 9.4.2 Turbidity Sampling and Analytical Requirements 271
- 9.4.3 Inorganic Chemical Sampling and Analytical Requirements 272
- 9.4.4 Pesticide and Organic Chemical Sampling and Analytical Requirements 275
- 9.4.5 Radioactivity 276
- 9.4.6 Quality Control 277

9.5.0 Quality Evaluation 277

9.6.0 Public Information 277

9.7.0 Operational Control Testing 278

- 9.7.1 General 278

SECTION Page

9.7.2 Minimum Operational Control Tests 278

9.7.2.1 Disinfection 279
9.7.2.2 Ion Exchange 279
9.7.2.3 Fluoridation 279
9.7.2.4 Softening 279
9.7.2.5 Iron and Manganese Removal by Chemical Precipitation 279
9.7.2.6 Turbidity Removal 279

9.7.3 Chlorination Control 280
9.7.4 Mixing Control 280
9.7.5 Sedimentation Control 280
9.7.6 Coagulation-Filtration Control 281

9.7.6.1 Available Techniques 281
9.7.6.2 Jar Tests 282
9.7.6.3 Techniques Based on Particle Charge 283
9.7.6.4 Continuous Filtration Techniques 285

9.7.7 Turbidity Monitoring 288

9.8.0 Laboratory Control 289

9.8.1 General 289
9.8.2 Physical and Chemical Examination of Raw and Treated Waters 290
9.8.3 Checking and Reporting Results 290
9.8.4 Laboratory Facilities 290

9.8.4.1 Disinfection Only 291
9.8.4.2 Ion Exchange 294
9.8.4.3 Fluoridation 295
9.8.4.4 Softening 296
9.8.4.5 Iron and Manganese Removal by Chemical Precipitation 297
9.8.4.6 Turbidity Removal 297
9.8.4.7 Laboratory Layout 298

9.9.0 Laboratory Personnel and Staffing 299

Rationale for Surveillance Standards 301

9.1.0 Surveillance 301

9.2.0 Responsibility 301

9.3.0 Source and Facilities Surveillance 301

9.3.1 Reliability of System 301

SECTION Page

9.3.2 Source 302

9.3.2.1 Surveys 302

9.3.3 Treatment 302
9.3.4 Water Supply Systems 302

9.4.0 Sampling Frequency 302

9.5.0 Quality Evaluation 303

9.6.0 Public Notification 303

9.7.0 Operational Control Testing 303

9.7.1 General 303
9.7.2 Minimum Operational Control Tests 303

9.8.0 Laboratory Control 303

9.8.1 General 303
9.8.2 Physical and Chemical Examination of Ray and Treated Waters 305
9.8.3 Checking and Reporting Results 305
9.8.4 Laboratory Facilities 305

9.9.0 Laboratory Personnel and Staffing 306

X. PERSONNEL

Summary of Personnel Standards 307

10.1.0 Personnel - General 307

10.2.0 Organization 307

10.3.0 Treatment Plant Staffing 309

10.3.1 Raw Water Quality and Unit Processes 311
10.3.2 Plant Layout 311
10.3.3 Disposal of Plant Wastes 311
10.3.4 Productivity of Labor 311
10.3.5 Climate 312
10.3.6 Training 312
10.3.7 Automatic Sampling, Monitoring and Control 313
10.3.8 Outside Contracts for Work 313
10.3.9 Staffing Pattern 313
10.3.10 Age and Condition of Equipment 313
10.3.11 Operation at Less Than Design Flow 314

SECTION Page

10.4.0 Suggested Training Programs 314

10.5.0 Education, Training, and Experience 315

10.6.0 Certification 315

10.7.0 Safety 318

Rationale for Personnel Standards 321

10.1.0 Personnel - General 321

10.2.0 Organization 321

10.3.0 Treatment Plant Staffing 322

10.4.0 Suggested Training Programs 322

10.5.0 Education, Training, and Experience 323

10.6.0 Certification 324

10.7.0 Safety 324

BIBLIOGRAPHY

I. General Design Considerations I-1

II. Source Development II-1

III. Treatment III-1

IV. Chemical Application IV-1

V. Pumping Facilities V-1

VI. Storage VI-1

VII. Distribution System VII-1

VIII. Operation and Maintenance VIII-1

IX. Surveillance IX-1

X. Personnel X-1

APPENDIX A. GLOSSARY OF TERMS A-1

APPENDIX B. TYPICAL JOB DESCRIPTIONS B-1

APPENDIX C. WHERE STANDARD DOCUMENTS AND REFERENCES CAN BE OBTAINED C-1

INTRODUCTION

A public water system may involve source of supply, treatment, storage, and distribution and is defined as a system for the provision of piped water for human consumption, if such system has at least 15 service connections or regularly serves at least 25 individuals. Most states require the approval of plans and specifications for such public water supply facilities before construction begins. Plant additions and major alterations as well as entirely new installations come under this provision. Approval is generally the responsibility of a division or bureau of sanitary engineering within the state department of health. Over the years, state review agencies have established minimum design requirements or standards based on good engineering practice, local conditions, and experience. New facilities are required to be in accord with these standards. Departures, if proposed, must generally be supported by special engineering studies, but may be necessary due to differing geographic and other circumstances.

The design engineer is advised to meet with representatives of the state's review agency in the early stages, preferably during preparation of a preliminary report. Needless delay is avoided if an early general agreement is reached on a proposed solution and basic design data. Because of their experience and knowledge of local conditions, state engineers are often able to contribute helpful information to assist the designer. During the preliminary and subsequent meetings with state officials, factors having an important bearing on the project will often be disclosed.

Early in design, consultation is recommended with regional and local planning boards and commissions, and government agencies to obtain as much basic information concerning the proposed project as possible. Careful preparatory work is time consuming but may eliminate expensive changes and revisions in the final design stage, during construction, and after completion.

Some states require water utilities to have an approved comprehensive plan of development for correction of existing deficiencies and to meet project future needs.

The design engineer should be familiar with all laws and regulations that apply to the project. Knowledge of local building and consturction codes is especially important.

This manual has been prepared to present information on federal requirements and regulations and as a further guide to professional engineers responsible for the design and construction of public water supplies. It is also intended to assist those engaged in the operation and surveillance of water systems in complying with federal requirements, and to encourage plant operators to act on their own initiative to improve system performance.

The design of water systems should not be limited to minimum requirements, but should meet the needs of the particular situation. Conditions may require the application of more stringent criteria. The judgement of the skilled professional engineer is required to properly apply the information set forth in this manual to the requirements of the particular project under design. It is intended that designers retain the maximum freedom of choice consistent with modern sanitary practice. It is recognized that each water supply system is an individual problem and that certain changes to these standards will be necessary to meet local conditions and unusual circumstances. Designers should explain deviations from design policies at the time projects are submitted for approval to the State.

The use of new processes and equipment is encouraged, but reliable engineering data supporting such use must be made available before approval can be granted.

The federal regulations are aimed at securing water works facilities which will make it possible under all conditions of operation to produce and distribute a finished product which will comply with the current Federal Drinking Water Standards in all respects.

All water system facilities and appurtenances shall be designed and constructed with due consideration to environmental impact, particularly with respect to location, esthetics, and disposal of plant wastes. They shall be designed with ample safety factors and shall be free of structural and sanitary hazards. They shall be of such size and capacity as to meet minimum pressure requirements.

When a new source of supply is proposed, samples of raw water should be examined in an approved water laboratory for chemical quality as early in the course of the project as possible. In the case of a new well, the sample should be collected before the pump is set and the well house completed. It is usually cheaper to abandon a test hole or a partially completed well rather than to attempt to treat a water of unacceptable chemical quality.

A final inspection of the completed work by a representative of the State may be necessary before the new facilities are placed into service. Before the new works are used to supply water to the public, representative samples of water taken from the system should be analyzed in an approved water laboratory and shall show the water to be in conformance with the Federal Drinking Water Standards.

One of the most important features for the designer to consider is simplicity of operation. He should plan or select apparatus with a view to having it so made and installed that it will be difficult to operate in any way other than that in which it was intended to function and with a minimum of attention.

Certain inherent differences between large and small plants must be recognized. Financial limitations in initial construction costs and operating funds are the most potent factor influencing the design of small plants. The methods of handling, storing, and feeding chemicals and the method of operating filter valves illustrate differences between large and small plants which must be considered. Plants or devices which require constant attention are not suited to small cities which may be unable to provide three-shift operation because of financial considerations.

The treatment plant is generally seen as having the major influence on water quality, but source of supply and the distribution system are also factors in this regard. All parts of the water system must receive due consideration with respect to their influence on water quality if economic production of good quality water is to be achieved. Special attention must be given to protection of the water supply against contamination by man, insects, animals, birds, and waters that are unsafe for domestic use.

Experience clearly shows that well designed and properly operated water systems can do the job expected of them in producing and delivering high quality water. Responsibility for proper operation rests mainly with water utility management, but the treatment plant designer also has an important role in this area. By selection of facilities and equipment suited to the anticipated skills and experience of operators, and by arrangement of facilities to promote safety and ease of operation, he can do much to assure successful system performance.

The training, the experience, the diligence, and particularly the interest of the water utility employees are the keys to success of the good operation and proper functioning of the entire water supply system.

This Manual is developed in ten sections. Each section is made up of two parts, a Summary of Standards and a Discussion of Design Parameters and Rationale for Standards. At the end of the Manual are a Bibliography, Appendix A containing a glossary of terms, Appendix B containing job classifications, and Appendix C giving information on where to obtain reference materials.

SECTION I. GENERAL DESIGN CONSIDERATIONS

This section covers the general considerations involved in: (1) the planning, (2) capacity and sizing of water system components, (3) the siting and arrangement of facilities, (4) plant and building layout and design, (5) standby power and emergency operations, (6) the disposal of plant wastes, and (7) use of new processes and equipment. Detailed design considerations are covered in the sections which follow.

SUMMARY OF STANDARDS -

GENERAL DESIGN CONSIDERATIONS

1.1.0 Planning

a. Prepare comprehensive plan for development of the water system. Consider grouping or regionalization of water systems where this is appropriate.

Where two or more alternate solutions exist for providing public water supply facilities, each of which is feasible and practicable, present to the State the alternate plans and justify the plan recommended, including financial reasons.

b. Consider the environmental and economic impact of the water system development, particularly of facility location and provisions for disposal of plant wastes, and file the necessary statements and reports required by PL 92-500.

c. Check conformance of the proposed plan of water development with state, regional, and local land use plans and zoning. Also consider water rights and future uses of source by other systems. Discuss with appropriate officials.

d. Schedule phased developments.

1.2.0 Capacity and Sizing

a. Forecast water demands. (I-3)*

b. Design supply and production facilities to meet projected maximum daily demand. (I-3)

c. Design distribution system and finished water storage to meet peak hourly demands and fire requirements. See Sections VI and VII, and "Rating Schedules for Municipal Fire Protection", Insurance Services Office, 160 Water St., New York, New York, 10038. (The Insurance Services Office was formerly called the National Board of Fire Underwriters.)

d. Provide pressure zones to maintain distribution system pressures of 1.76 to 7.03 Kg/Sq. Cm. (25 to 100 p.s.i.). (VII-3)

---

*(I-3) = Bibliography, Section I,
Reference No. 3

1.3.0 Siting of Facilities$^{(I-30)(I-3)}$

a. Flooding - Wells, water treatment plants, access roads, and power supply lines should be located above the 100 year flood plain elevation, or adequately protected against flood.

b. Consider relative locations and distances between source of supply, treatment plant and service areas in selecting optimum site.

c. Evaluate soil characteristics, foundation conditions, and groundwater level.

d. Establish the presence of any potential sources of pollution or other factors which may influence the quality of the supply or may interfere with the effective operation of the water works system.

e. Determine the availability of electric power, natural gas, sanitary and storm sewers, and other utility services to pump station and treatment plant sites. Duplicate primary sources of electric power are desirable (see Section 1.5).

f. Consider the convenience of rail and highway transportation to plant sites.

g. Consider the topography of the plant site with respect to relative elevations and layout of plant structures, site grading, drainage, and provisions for walks, driveways, and access roads.

h. The size of the plant site should be adequate for present needs and projected future expansion including space for adequate disposal of treatment plant wastes, see Section 1.6.0.

i. The cost of land and the expense of clearing, grading, and otherwise preparing the site are factors to be included in comparing alternate sites.

j. Investigate the possibility of any special problems regarding easements or right-of-way acquisition for raw or treated water pipelines, drains, or power lines to pump station or plant sites.

k. Consider the plant surroundings including the proximity of residences and industrial establishments, the natural beauty of the site, the need for a buffer zone and landscaping, and the attitude of the public toward use of the site for a treatment plant.

l. The location of the plant property from the standpoint of civil defense is important. A site remote from key target areas and natural hazards such as earthquakes and landslides is preferred.

1.4.0 Plant and Building Design Parameters(I-3)(I-30)

1.4.1 The general arrangement of the plant should provide for structural security, functional efficiency, and convenience of operation.

a. Properly select and group units to facilitate operation and to permit effective supervision.

b. Centralize operations and control.

c. Eliminate operational irritants such as unnecessary steps and exposure of operators to weather for routine tasks.

d. Provide adequate lighting, heating, ventilation, and drainage.

e. Provide for accessibility of equipment for operation, servicing, and removal.

1.4.2 Building Design Considerations(I-3)(I-30)

a. Operator safety (consider OSHA requirements).

b. Flexibility of plant operation.

c. Arrangements for chemical unloading.

d. Need for separate rooms for chemical storage and feed equipment to reduce dust problems.

e. Need for dehumidification equipment in pipe galleries and other damp areas.

f. Economy of construction and operation.

g. Requirements for storage and shop space.

h. Need for sanitary facilities for operators and visitors.

i. Esthetic values and architectural style.

j. Plant design should provide protection against cross-connections. No conduit or basin containing filtered water should have a common division wall with another conduit or basin containing non-potable water. Vertical double division walls, where separated sufficiently to permit ready access for inspection, are permissible where the division walls are built without construction joints and are properly keyed into their footings.

k. Paints, coatings, sealers or liners used in pipes, tanks or equipment which convey or store raw, partially treated, or potable water should not present a toxicity hazard to consumers, and such materials should be subject to approval of the State. Pipes should be color coded in accordance with standard practices (see Rationale).

l. The plant capacity should be adequate for at least 25 years into the future, and the plant site and design should facilitate future expansion. Wall castings are recommended for future pipeline extensions.

m. For very large settling basins and other structures consideration should be given to the temperature effects on the structures of expansion and contraction.

n. Arrange plant so that chemicals are stored above feeders and so feed lines are as short as possible and are accessible for cleaning.

o. Automatic equipment should be selected with due regard to its reliability, ease of maintenance, and specific local factors governing the design in question. Automatic equipment should not be used if so complex as to be unlikely to be maintained by the available operating staff of the plant in question. Equipment which will automatically shut down a water treatment process may be acceptable, provided the process can be started and operated manually so as to enable the operator to select appropriate chemical doses and to make pertinent adjustments of the equipment when it is placed in operation. The designing engineer may supply supporting data justifying the proposed use of equipment which is fully automatic or of recent development.

p. The designer should take into account those factors which are influenced by the size of the plant including the financial, physical, and personal phases related to size of plant.

q. Smooth nose sample taps should be provided for adequate surveillance and monitoring of water quality, see Section IX.

r. Adequate protection should be provided for oil storage facilities to avoid contamination due to spills and tank rupture.

1.5.0 Standby Power and Emergency Operations(I-30)

a. Public water supplies should be designed and operated so as to provide adequate water service at all times. Failures which can be reasonably anticipated, such as power failure and mechanical breakdown, should be taken into account in the design of facilities.

b. It is recommended that multiple water sources be developed wherever possible in combination with an adequate emergency reserve of gravity reservoir storage (see Section VI).

c. In those instances where pumping from storage is necessary, multiple booster pumps are recommended which have sufficient capacity to meet peak demands plus fire demands with the largest pump out of service.

Auxiliary power units are recommended in those systems not having adequate gravity storage.

d. The possibility of damage to major transmission pipelines due to landslides, construction activity, etc. should be considered (see Section VII).

e. To assure reliability in any particular situation consideration should be given to duplicate equipment, feed lines from different power sources, on-site power generation, alternate fuel types and sources, and duplicate substations.

f. Plant access roads and power supply lines should be located above the 100 year flood level.

1.6.0 Disposal of Plant Wastes (I-4)(I-5)

a. The disposal of water treatment plant wastes including domestic wastes should conform to applicable local, state, and regional water pollution control laws and regulations. In addition, the EPA Effluent Guidelines Division is currently in the process of promulgating final effluent guidelines and standards for the water supply industry under Sections 301 and 304 of the Federal Water Pollution Control Act, 33 U.S.C. 1374, Publ. L. 92-500.

b. Water treatment wastes are subject to reclamation or disposal. Waste reclamation processes available include recycling and reuse of lime, magnesium carbonate, or alum. Filter backwash water can be captured and recycled to save water or to control pollution.

c. Disposal techniques include:

  (1) Discharge to sanitary sewers.

  (2) Discharge to lagoons.

  (3) Land disposal.

  (4) Sludge dewatering with ultimate disposal of residual wastes by barging to sea, which requires a permit under the Marine Protection, Research, and Sanctuaries Act, in landfill, by underground disposal, or by incineration.

d. The method selected for disposal or reclamation of plant wastes should be considered in the light of its environmental and economic impact.

e. Before selection of the treatment process, consideration should be given not only to the desired quality of finished water, but also to the nature and quantity of any wastes produced during treatment.

f. Consider environmental impact of all open salt storage areas. If necessary, provide adequate protection.

1.7.0 Use of New Processes or Equipment (I-30)

New treatment processes, unproven equipment, or unproven chemical additives may require submission of a report to the State on the results of a special study by the engineer.

New-process studies should conclusively demonstrate that proposed processes, new equipment and new non-toxic chemicals will produce water equal to or better than that required by the Federal Drinking Water Standards and should also be cost effective.

RATIONALE FOR GENERAL DESIGN CONSIDERATIONS

1.1.0 Planning

Comprehensive Planning for Water System Development

Engineers engaged in the design of water systems should strive to provide the best system possible and resort to minimum systems only when it is not economically feasible to do otherwise. Installation of small, minimal systems within the projected service area of an established water district or municipality often leads to serious problems. Usually, the smaller distribution systems do not measure up to municipal standards and must be replaced at considerable expense at the time the municipal system expands into the area. Also, if the designer of a small system is cognizant of existing municipal comprehensive water supply plans, he can, in many instances, minimize future problems associated with provision of municipal service.

It is extremely important, therefore, that small systems to be installed within the project service area of a municipal utility conform as nearly as possible to the comprehensive plan as well as the design and construction standards of that utility.

Fire fighting capability is a highly desirable feature of any public water supply system regardless of size. It is strongly recommended that all new public water systems be designed to provide fire fighting capability. The quantity requirement for fighting fires even in a residential area is sufficient to dictate minimum main size of 15 cm (6-inch) if looped or 20.32 cm (8-inch) if deadended. It is recognized that in some instances it is not possible to provide full fire flows in the initial stages of development; however, since the life of distribution mains is generally in excess of 20 years, it is wise to install mains sized to convey fire flows so that when fire flows are made available, mains will not have to be replaced.

In those cases where the ultimate anticipated project is of such size as to make it likely that full development will take several years, it may be advisable to break the project into successive phases or divisions. The following program of water system development and construction is suggested:

- A comprehensive plan for the ultimate water system should be prepared showing proposed water sources, storage facilities, pumping facilities, major water mains, number of lots to be served, proposed lot and street arrangement, and topography. The probable size, location, and sequence of each construction phase or division should be clearly indicated.

- Design and construction of the first phase or division may be based on the immediate requirements of that area alone, except as noted in the third paragraph which follows.

- As each successive phase or division is added, the system should be modified by addition or reconstruction, if necessary, to assure conformance with the Standards in this Manual.

- As the last phase is completed, the total system then existing should be substantially the system of the comprehensive plan.
- The original comprehensive plan may be revised from time to time, provided that the revised plan continues to meet the needs of the ultimate development.
- Certain features of any early phase of the ultimate system may be constructed to meet the ultimate design from the outset, when to do otherwise would result in repeated reconstruction at great expense and inconvenience to the public or result in unnecessary disruptions of service or present a hazard to health. For example, a water main serving two or more subdivisions to be developed at different times might reasonably be required to be constructed to its ultimate capacity at the time of initial installation. Fire insurance rates may be lower if supply is adequate.

In water development planning, the design engineer should incorporate the results of resource inventories and land use zoning. He should work closely with city, county, regional, and other planning commissions, and should determine and consider public attitudes and values related to the water development. He should prepare an environmental assessment early in the preliminary planning stage.

The location of intakes, wells, pump stations, treatment plants, and storage tanks and reservoirs are usually of much public interest and concern, as are architecture, landscaping, air and water pollution control, noise abatement, traffic generation, and similar items.

The engineer is urged to become familiar with and use the modern ecological approach to planning. This may involve the combined efforts of a number of specialists such as acoustical engineers, fisheries biologists, and others.

Regionalization of Water Systems

Regionalization of water systems is the grouping of water supply systems within a regional area for management purposes and, to the extent feasible, for physical connection and integration for supplementation of supply and services. This differs from the regional planning and control of water resources.

In following paragraphs, the existing situation as to system sizes is illustrated; the effect of size of system on proper functioning is discussed; and the desirability for regionalization is indicated.

Of the nearly 40,000 public water supplies in the counterminous United States over 80 percent service less than 5,000 persons (I-45).

Operators of filtration plants, especially those serving the larger communities, constantly strive to produce water better than that defined by public health standards. The smaller systems, which comprise a large majority of the waterworks in the United States, frequently find it difficult to provide water complying with established standards)I-45). In fact, many small public water supplies fail to meet all aspects of the quality standards on a continuous basis.

The quality of service from many small public water supply systems is far from satisfactory. Water supply in the United States is essentially small business enterprise. The average size supplier has fewer than 2,000 customers. Deficiencies in quality have been shown to be inversely proportional to the size of the water supply systems.

Most small supplies do not have the services of full-time qualified operators nor do they have the benefit of quality engineering in their conception, design, and construction. Droughts have shown large numbers of these supplies to be inadequate. To meet the problems of those not served, and of those served inefficiently from small poorly managed supplies, a program of regionalization may be needed in some areas. Incentives at the state and national level might assist regionalization.

Benefits which may result from regionalization of water systems are summarized below:

- Consolidation may make possible more efficient operation and often is the only way a small community can provide the kind of service its public expects and deserves.

- Financing may become possible, whereas smaller systems may find it harder to enter the money markets.

- Policies and practices can be modernized.

- Better supervision can be obtained; full-time staff of top level personnel and sufficient trained manpower for operation can be hired.

- Automated equipment and advanced technologies that are beyond the means of small systems become feasible and advantageous.

- Economy of scale can be obtained, requiring development of fewer but better facilities.

- Better raw water quality can result. Many of the water quality problems are created by influences upon the raw-water which are beyond the control of the water purveyor. Regionalism can correct many of the difficulties under some conditions.

- A better quality and more consistent product is more likely to be delivered to consumers.

- More adequate and reliable service would be possible.

Regionalization of water supplies would also be of benefit by reducing the load of state health department surveillance. The Community Water Supply Study (I-45) estimated a saving to the state of 4 man-days each year, or $350, per each system eliminated by merger. The Study showed that the larger systems provide better laboratory control, attract and hold better operators and have an increased probability of meeting the bacteriological surveillance criteria. The smaller systems have more difficulty in delivering water with satisfactory quality than the larger systems. This is particularly true of the many systems serving 500 people or less.

To obtain the benefits of regionalization, the fringe of small operations around the major water purveyors of an area should be eliminated. Future population increase in major metropolitan areas will tend to accelerate the need for, and the trend to, regionalization of water supply developments.

One of the tasks that the water utility must confront is consolidation -- when consolidation makes sense. There are a number of opportunities where consolidation would be wise, economical and logical. There are others where it is not obvious whether it would be economical or sensible. Individual cases must be looked at, not superficially but specifically. Smaller utilities are often very widely scattered so that consolidating them physically often is improbable, but consolidation for planning purposes may be attractive.

Approaches to determining the timing in terms of regional growth for regionalization and to accertaining the financial feasibility of regionalization of water systems are well presented by N.C. Williams and J.M. Redfern in "The Financial Feasibility of Regionalization" which appeared in the Journal of AWWA in March, 1973, pages 159 to 168.

1.2.0 Capacity and Sizing

Forecasting Water Demands. Predicted future water demands are the basis for sizing water system facilities. Studies to forecast water demand should consider population, commercial and industrial growth, water use trends, metering and extension policies, and service area boundary changes (as might occur through annexation). How far future needs should be anticipated depends upon the nature and permanance of the structures, and upon the cost of capital. An equitable division of the financial burden between the present and future consumers suggests that provisions be made for 10 to 30 years in advance of present requirements. Accurate records of past growth and water demands are especially valuable in forecasting studies. Many techniques or procedures are available for these studies and often more than one should be employed and the results compared.

The various methods for predicting the growth of towns and cities are all based either upon the past growth of the city under consideration, or upon the growth of similar and larger cities. Methods dependent upon past growth are: (1) graphic projection; (2) arithmetical increase; (3) percentage increase; and (4) decreasing percentage increase.

The graphic projection is made by plotting populations vertically and years horizontally on a coordinate chart, and then drawing through the points a smooth curve projected into the future. The knowledge and bias of the person making the projection will be reflected in the estimate obtained.

An arithmetical forecast is made by adding to the present population the product of a fixed sum multiplied by the number of future years it is desired to include. The fixed sum is the annual growth during a few past years. The method generally gives results too small except for those cities which are limited in their territorial growth, and for population increases which are dependent almost entirely upon increased density.

In using the percentage increase method, the percentage of increase in population during the previous decade, or the average of several past decades, is determined. This percentage is assumed to be constant for all future decades and is applied to each succeeding decade in turn. Results are usually too large except for rapidly growing cities.

A modification of the preceding method makes use of a decreasing percentage of increase in population each succeeding decade. The amount that the percentage will be decreased each decade will depend upon the previous rate of decrease as revealed by census statistics of the municipality in question and upon the judgment of the forecaster.

The method which utilizes the experience of larger cities is quite popular. The growth of the city in question is plotted upon a chart, with years as abscissas and population as ordinates. The growth curves of several larger cities, preferably those having similar geographical and commercial characteristics, are plotted on the same chart in such a way that they all pass the present population of the city under consideration. With the curves from these other cities as guides, the population curve of the city in question is then projected into the future.

Obviously, any forecast which is to be more than a rough approximation must be preceded by a careful analysis of all the factors affecting the community as well as long time records and trends of the particular community and of similar communities. In any event the accuracy of such forecast will in a large measure depend upon the skill and experience of the observer. A competent forecaster is recommended.

Recently forecasting has been complicated by the concern of some environmentalists with overpopulation, and water utilities must explore ways to meet actual future needs in the light of demographic changes. If the other factors are favorable, people will move into an area despite a shortage of water. The shortage of water will result in many problems, including health problems. Attempts to use water as a means to control population may result in a diminished standard of living rather than in a restricted population.

Using forecasts of water demands, a logical program or plan for development of treatment facilities may be established. Involved are decisions to build initially for ultimate needs or to provide for development in steps. Six factors which have a bearing on the period of design of treatment facilities are: (1) the useful life of facilities, (2) the ease of extension, (3) the rate of growth of the service area, (4) the rate of interest on the loan, (5) the change of purchasing power during the debt period, and (6) the performance of the facilities during the early years.

A common approach is to provide initially those portions of the ultimate plant that may not be built economically and conveniently in stages, and to provide the other facilities in steps as the need develops. Structures like pumping and chemical buildings fall in the former category, and tanks and filters in the latter. Initial investment is thus kept lower, releasing funds that would otherwise be tied up in unused facilities.

A second approach comprises gradual development through the construction of independent treatment units. Water systems may grow at a more rapid or slower rate than predicted. Water utility managers are therefore advised to compare actual water demands with those predicted for the design of their treatment facilities. Timing for expansion of facilities may thus be advanced or delayed as necessary.

Source of supply works and treatment plants should be capable of delivering to the distribution system dependably and safely the water requirements of the maximum day of use. Supply and treatment facilities shall be of such capacity that an outage of any individual unit during a period of peak demand will not reduce the supply below the water requirements of the maximum day. In the absence of metered data, maximum daily flow is often estimated to be 1.5 times the average daily flow.

High service pumps, distribution mains and treated water storage facilities are sized to meet peak hourly demands and fire requirements. See "Rating Schedules for Municipal Fire Protection" and "Guide For Determination of Required Fire Flow" as published by the Insurance Services Office, 160 Water Street, New York, New York, 10038. In the absence of metered data peak hourly flow is commonly assumed to be 2.0 times maximum daily flow or 3.0 times average daily flow.

Expansion of a water system is indicated when the demands on the system approach 80% of the rated capacity of existing facilities. As a general rule, steps to provide additional capacity should be taken at least 10 years before present capacity is reached to allow sufficient time for engineering investigations and design, environmental and economic impact requirements, financing, and construction.

Distribution System Pressures

An adequate supply of water is essential to maintain the bacteriological quality of the water in the distribution system. Low pressures in the mains produce conditions favorable to contamination of the water by sewage or other polluting substances through back-siphonage, cross-connections, and faulty plumbing.

Normal operating pressure at the service connection should not be less than 1.76 Kg/Sq. Cm. (25 pounds per square inch gauge, p.s.i.g.) nor more than 7.03 Kg/Sq. Cm. (100 p.s.i.g.), except that during periods of hourly maximum demand during peak seasonal loads the pressure should be not less than 1.4 Kg/Sq. Cm. (20 p.s.i.g.) and that during periods of hourly minimum demand the pressure should be not more than 10.55 Kg/Sq. Cm. (150 p.s.i.g.). Variations in pressures under normal operation should not exceed 50 percent of the average operating pressure. The average operating pressure should be determined by computing the arithmetical average of at least 24 consecutive hourly pressure readings. Excessive pressures may cause leaks and waste of water and may increase the possibility of damage from water hammer.

New water systems, or new pressure zones in existing water systems supplying customers at substantially constant elevation should be designed to maintain an operating pressure at the service connection of not less than 1.76 Kg/Sq. Cm. (25 p.s.i.g.) nor greater than 7.03 Kg/Sq. Cm. (100 p.s.i.g.).

1.3.0 Siting of Facilities

The engineer should evaluate available sites to determine the most favorable location for the plant. Acquisition of an attractive location in terms of both construction and operation is enhanced when sites are plentiful and land costs are low. Many utilities plan for the future by acquiring property years in advance and before the number of suitable sites becomes limited. Foresight is to be encouraged, although it is important that site purchase be based on a study of future water supply requirements. Where the utility has not set aside land for the future plant, and where suitable sites are scarce and land costs are high, site selection and acquisition are likely to be time consuming and expensive. In such instances, careful engineering and legal surveys and appraisals should be made before negotiations to purchase property are begun.

Certain basic information about the proposed plant is needed before undertaking a site survey. An accurate estimate of the area required for the ultimate development of the plant is especially important. This can be determined by a rough layout of the plant, including treatment tanks, buildings, pumping and storage structures, and other facilities. The general territory convenient to the source of supply and the service area may then be surveyed, less promising locations screened out, and those tracts that appear well suited for the proposed development subjected to further study.

A comparative study of sites involves a number of considerations. It is highly desirable to locate wells, water treatment plants, and power supply lines above the 100 year flood plain elevation. In some cases it may not be possible to do so, but it may be acceptable to provide protection of these items from flooding.

Lake and river intakes and other structures located so as to impede normal or flood flows may require approval of a regulating authority.

The location of the site relative to the source of supply should be known, as well as the present and future limits of the service area, as the economy of conveying water to and from the plant is an important factor. Any special problems relative to acquiring land or easements for raw and finished-water pipelines should be investigated. The engineer should establish the presence of potential sources of pollution or other factors which may adversely affect water quality or interfere with effective operation of the water works system.

The availability of electric power must be ascertained. A site linked to more than one source of outside power is to be favored with respect to continuity of operation. This is especially important in places where electrical storms are frequent and where exposure to natural elements such as hurricanes, tornados, sleet, or snow is great. The availability of natural gas, sanitary and storm sewers, and other utility services are also factors to be considered.

The convenience of transportation facilities such as railroads and highways at the site can be very helpful, as they provide delivery of materials and equipment during construction, and of supplies and chemicals during operation. Operating costs, particularly for larger plants, are reduced substantially if bulk shipments of chemicals can be made. Physical characteristics and topography of the site may affect construction and pumping requirements. Flooding, foundation conditions, groundwater level, and site preparation, including clearing, grading, and drainage, all are factors which directly influence the cost of the plant.

The shape of the site is important. It should accommodate the plant and future additions without resorting to an overly expensive arrangement or one which does not lend itself to convenient operation. The land available and its cost should be considered. A site providing surplus area is to be favored as future needs often exceed the best estimates. The disposal of plant wastes should be considered. Land requirements vary widely depending upon chemicals and processes used, and large areas may be required.

The importance of the natural beauty of the site and good architectural design should be appreciated. Construction of an attractive plant is in keeping with a good public relations program.

The attitude of the public toward use of the site for a treatment plant should be considered. The purchase of additional land as a protective barrier, or special building construction to prevent noise, may be advisable to gain the acceptance of nearby property owners and to avoid complaints. Nearby waterways and their water quality and use should be considered.

The location of the property in terms of civil defense is an important item. A site remote from key target areas, such as large cities and defense plants, is favored in this regard. This may, of course, be impractical in some places, and reliance then must be placed on construction.

Considerations should also be given to location with respect to natural hazards such as earthquakes, landslides, high tides, and the like.

In the final analysis, selection of a site will depend on an analysis involving construction and operating costs and a judgment of the factors which cannot be expressed in dollar values. As mentioned above, the site should be adequate for ultimate needs.

1.4.0 Plant and Building Design Parameters

1.4.1

General Arrangement. In planning the layout for a water purification plant there are five main factors to consider: (a) structural security, (b) functional efficiency, (c) esthetic values, (d) economy of design and operation, and (e) provision for future expansion.

In the absence of a sound earth or rock foundation, suitable means should be employed to prepare the foundation properly for the loads to be applied. Settlement of poor foundations adversely affects the safety efficiency, appearance and economy of the plant.

Functional efficiency is dependent on several design factors. Most important are the proper selection, sizing, and sequencing of the treatment processes to suit the quality of the water to be purified. Each step in the water treatment process following filtration should be designed to protect the water against possible contamination. Functional efficiency is furthered by grouping of units to facilitate operation and to permit effective supervision. Operations and control should be centralized as much as possible. Most operator attention is required for control of flocculation, chemical feeding, filtration, and filter backwashing, therefore the structures and equipment for these functions should be located close together rather than widely separated. On the other hand, settling basins may be placed some distance away, as the results of settling can be seen by observing the clarity of water entering the filters. It is desirable to plan the various parts of the plant in such a way: (1) as to reduce the lengths of connecting conduits; (2) make a wall do double duty, where practicable, by using it as a dividing wall between two structures if no possibility of contamination by leakage is thereby introduced; (3) provide properly designed mechanical equipment; (4) as to use automatic controlling, measuring, registering, and recording devices; (5) provide laboratory properly equipped for the work to be done; and (6) provide convenient access from one part of the plant to another.

Operations and equipment can be simplified by using the smallest number of units which is feasible, provided the number is sufficient to provide standby capability.

Make chemical feed lines as short and direct as reasonably possible. Plant operators have much more difficulty with chemical feed lines than with water conduits. It therefore yields operating simplicity and reliability to bring the water to the chemicals when the arrangement of the plant permits. For this reason, in many plants, the rapid mix is placed in the chemical building, settled water passes through the building or past it en route to the filters, and filtered water passes through the building where it may receive post-treatment before being distributed. This is recommended.

Use simplified chemical handling and feeding. This includes such items as the use of outdoor filters in mild climates, earthfill over settling basin slab roofs in very cold climates, and use of steel tank units where appropriate. Water utility structures are often used as long as 100 years, and it ordinarily does not make sense to provide a type of construction that will last only a few years.

Attention should be given to elimination of operational irirtants such as unnecessary steps, needless exposure of operators to weather in their performance of routine tasks, awkward or hazardous operations, unreasonable frequency in filling chemical hoppers or tanks due to insufficient storage capacity, inconvenience due to poor lighting or heating, and the lack of proper dressing or toilet facilities.

1.4.2 Building Design Considerations

Filter building designers should take into account many factors including operator safety, flexibility of plant operation, need for separate rooms for chemical storage and feed equipment to reduce dust problems, dehumidification of pipe galleries and other damp areas, economy of construction and operation, provisions for chemical delivery and unloading esthetic values, architectural style, protection against contamination, the need for shop and storage space, accessibility for operation, servicing and removal of equipment, temperature effects on large structures, and provisions for future expansion.

Due consideration of esthetic values suggests that the plant, in itself, and in so far as practicable, both inside and out, be a thing of architectural beauty, rather than an eyesore, and that it be in keeping with both its purpose and its surroundings.

Frequently, there is a question of how much weight should be given to provision for future expansion. A general rule was stated many years ago that a plant for the purification of water should be designed to take care of the community's needs for twenty years in the future. As a general rule, that still holds, but it is subject to considerable modification. In the case of a small plant, it may be possible to effect some economics in operation if the plant is build larger than otherwise needed, in order to permit of single-shift or two-shift operation. In the case of larger plants, a forward look may indicate that any additional facilities be located at some other point in the system. In very large plants, or in cases where there is great delay in securing authorization of the work, the twenty-year period, measured from the time the work was first projected, may be insufficient. Sometimes the capacity of a given source of supply is limited in such a way as to preclude the possibility of any material extension in the future.

In any case, where there may be a call for future extension within a reasonably short interval of time, studies should be made to insure that suitable extensions can be made at reasonable expense, but, except in unusual circumstances, no great sacrifice of present economy or efficiency should be made in order to provide for future extension.

Even at times when interest rates are low, the extra expenditure to provide for future expansion at compound interest, must be less than the future expenditure made necessary by the omission of such provisions. Also, it may not be wise to commit future development to a definite line of action.

In order to facilitate identification of piping in water works pumping stations and plants it is recommended that the following color scheme be utilized for purposes of standardization:

Water Lines	
Raw	Olive Green
Settled or Clarified	Aqua
Finished or Potable	Dark Blue
Chemical Lines	
Alum	Orange
Ammonia	White
Carbon Slurry	Black
Chlorine (Gas and Solution)	Yellow
Fluoride	Light Blue with Red Band
Lime Slurry	Light Green
Potassium Permanganate	Violet
Sulfur Dioxide	Lt. Grn. with Yellow Band
Waste Lines	
Backwash Waste	Light Brown
Sludge	Dark Brown
Sewer (Sanitary or Other)	Dark Gray

Other

Compressed Air	Dark Green
Gas	Red
Other Lines	Light Gray

If the situation develops where two colors do not have sufficient contrast to easily differentiate between then it is suggested that a 6" band of a contrasting color be painted on one pipe at approximately 30" intervals. The name of the liquid or gas could also be painted on the pipe. In some cases it may be advantageous to paint arrows indicating the direction of flow.

Designers should provide only essential instrumentation. It is useless to burden the operator with more instrumentation than is needed. It will be neglected and will not be used. If in doubt, omit the dubious instrument, but provide space for its subsequent installation.

Make appropriate use of automation. Full automation on the sole source of supply for a community can be a mistake. A failure of automatic equipment could then cause a complete failure of the supply, unless there were a bypass arrangement, an alternate source, or extensive storage. Automation of facilities such as iron removal plants may be justified, for little permanent damage is done by a temporary bypass. Where a community has several sources of supply that are reliable, automation of individual units becomes much more acceptable.

Design As Affected By Size of Plant

Certain inherent differences between large and small water treatment plants should be recognized by the designer. These differences exist in at least three phases of the work, they are the financial, physical, and personal phases. There are enough local variables to require modification of general suggestions to fit actual conditions.

Engineering decisions always involve cost considerations. In small towns the financial situation often is one of the most sifnificant factors influencing design.

If it is accepted as true that good engineering consists in securing maximum results at a minimum cost, the designer of a small plant has an opportunity to show his resourcefulness and do some excellent engineering. He should accept cost limitations frankly at the outset and not try to make his plant a miniature replica of some larger one.

On a small job it often happens that many details are encountered that are really difficult of solution and should be given very careful consideration. Even when very rigid economy is necessary, good workmanship and materials should be insisted upon, as the acceptance of anything else means future trouble and expense. Economy may be secured by compactness in the arrangement of buildings, energy conservation, and the grouping of all structures so that they are adjacent to one another instead of being separated by wide spaces which necessitate expensive outside piping, walks, or roads.

The superstructures of buildings should be studied carefully in order to secure a pleasing appearance by the general arrangement and proportion of the structure, rather than by use of materials or details furnished simply for the purpose of embellishment. In the hands of a good designer, a beautiful building can be built at less cost than an ugly one designed by one who lacks such ability.

In considering the effects of the physical phase on large and small plants, there are some advantages which may be exploited by the designer planning a small plant. A small plant may sometimes be located so that the topography of the surrounding ground may be used to reduce construction and operating costs. Filters may be placed on a side hill so that they may be built directly on the ground and the effluent piped to a reservoir in an adjacent low spot. Occassionally, a pipe gallery can be placed on one side of the filter to secure daylight and an entrance from the ground level. Chemicals, in such instances, can sometimes be trucked to a store room or discharged directly into storage bins, or wash-water tanks may be built on high ground adjacent to the filters. Large plants can seldom take full advantage of such conditions because of the wide area covered by the various structures.

The matter of handling and storing of chemicals should be treated differently in small and large plants. In large plants, where the nature of the chemicals permits, they should preferably be received in bulk, and should be elevated and discharged mechanically into overhead bins by bucket elevators, or by air. They should be withdrawn by gravity wherever possible. Liquid chlorine should be received in ton containers, and the necessary equipment should be provided for handling them with ease and safety.

In small plants, chemicals can be handled best in bags, each bag containing exactly the same weight. In that case they can be handled easily and, by counting the number of bags used for each batch each day, the exact amount used can be determined without the necessity of weighing.

Large filters could not possibly be operated without the use of hydraulically or electrically actuated valves and some mechanical device for controlling them; but such equipment is expensive and necessitates considerable attention which is not always available in small plants. When the valves are small, very satisfactory operation can be secured without such equipment by using wheel stands on the operating floor.

In small plants, joints for taking care of expansion and contraction, due to temperature changes, can generally be neglected, but in a large plant they should receive most careful consideration because of the greater structure lengths.

The physical difficulties encountered in designing a small plant are generally much less than those in a larger one, but the designer will find problems of a financial or personal nature constantly intruding to modify otherwise satisfactory plans.

The personal phase, that of building and making the plant operate as the designer intended, is extremely important and deserves extensive and detailed consideration by the engineer. Specifications should be written so that they can be clearly understood and so that they cannot be misunderstood. Apparatus should be planned and selected with a view to securing an installation which will be difficult to operate in any other way than that intended. The designer should make it easier for the attendant in charge of operation to do the right thing - easier than to do the wrong thing.

1.5.0 Standby Power and Emergency Operations

All aspects of community life, domestic, commercial and industrial, are constantly dependent upon water service. Public water supplies must be designed and operated so as to provide adequate service at all times. Failures which can be reasonably anticipated such as power failure and mechanical breakdown, should be taken into account in the design of facilities. Duplicate basins, equipment, and pipelines should be provided as necessary for continuous operation.

Reserve capacity contributes to plant reliability. Reserve capacities for contingencies may be set up in either one of two ways: (1) by using conservative design criteria or (2) by using carefully derived maximum-value criteria and adding reserve units. For example, unless the plant can be taken out of service for a substantial period of time for repair and maintenance work, not less than two of any important items, such as settling basins, flocculators, or filters should be provided. The degree of standby provided is also an index of the importance of the item under consideration. It is not usual to provide a spare chemical feeder for corrosion control or for fluoridation but it is usual to provide a spare coagulant feeder when turbid water is expected, and a spare chlorinator is always provided. When continuity of pumping is essential, a spare pump unit should be provided.

In many instances, the units under consideration may not be absolutely essential, and the plant will function moderately well without them for a limited period of time. For example, a plant having two settling basins may function reasonably well with only one.

An additional factor to be taken into account is the degree of risk involved. When the plant is treating a water that is highly contaminated, a more conservative allowance for standby units should be made than might be required for a treatment such as iron removal alone.

Whenever possible it is recommended that multiple water sources be developed in combination with an adequate emergency reserve of gravity reservoir storage.

In situations requiring pumping from storage, multiple booster pump units are to be installed which have capacity to meet peak demands with the largest pump unit out of service. A good arrangement is to provide three pumps of equal capacity, any two of which can carry the load.

Except in those rare circumstances where power failure is not a legitimate concern, auxiliary power units should be installed for certain standby services, particularly in those systems not having adequate gravity storage. Standby power may be desirable so that water may be treated and/or pumped to the distribution system. High service pumping stations, treatment plants, and wells pumping directly into distribution systems should be equipped with standby power. Where practicable, emergency power should be available to produce and deliver not less than average daily demands on the water system.

Proper consideration should be given to possible damage to major transmission pipelines by landslides, excavation equipment, or other causes by proper valving and alternate routing of flow.

The best methods for achieving the desired reliability of water service vary with prevailing circumstances. Some of the methods to be considered include duplicate equipment, multiple off-site power sources, on-site power generation, use of direct engine drive, and provision for use of alternate fuel types and sources. Plant access roads and power supply lines should be located above maximum flood level.

1.6.0 Disposal of Plant Wastes

Discharge Regulations

Increasingly stringent waste discharge regulations have directed attention to solids generated from water treatment processes. The bulk of these solids is generated by chemical coagulation for the removal of turbidity, by chemical precipitation of hardness, or from backwashing of filters.

The Water Pollution Control Act Amendments of 1972 authorize the establishment of guidelines for all industrial discharges, including those from the water utility industry. The attainment of the national guidelines is envisioned as encompassing three well defined stages. Industrial discharges must achieve, as a minimum, the best practicable control technology by July 1, 1977, and the best available control technology not later than July 1, 1983. The elimination of pollutant discharge by 1985 is a national goal, with stream quality adequate for the support of fish and wildlife by 1983 as an interim goal.

In addition, local, state, and regional water pollution control laws and regulations are applicable to disposal of water treatment plant wastes.

Currently the EPA Effluent Guidelines Division is in the process of promulgating effluent guidelines and standards for the water supply industry under the Federal Water Pollution Control Act, 33 U.S.C. 1374, Pub. L. 92-500. Permits are required and can be issued under interim standards.

Sludges Produced

The sludges produced by coagulation and softening processes and filter backwashing in water treatment have long posed problems for handling and disposal. There are methods for dewatering and disposal of these chemical sludges. They have been used successfully in a few locations. However, there are wide variations in raw water quality and corresponding wide variations in characteristics of the sludge produced. This makes it difficult to predict the results from general application of such methods. At the present time, it appears best to approach each situation as a separate problem requiring individual attention and study.

As mentioned previously, sludges are drawn off from settling basins and are discharged in the backwashing of filters. Plants designed for clarification, iron and manganese removal, and softening all produce sludges. These sludges may be formed by addition of alum, iron salts, lime, magnesium carbonate, or polymers, and include silt, colloidal materials, and chemicals removed from the raw water.

Discharge of water-treatment-plant wastes into watercourses or lakes, historically the most widely used method for such waste disposal, may soon be virtually eliminated as an acceptable practice. Undoubtedly, some retain the viewpoint that when filter backwash waters or solids from sedimentation basins are returned to the water-course that served as the source of supply to the treatment plant they add no new impurities but merely restore to the water-course material that had originally been present, and thus are not polluting the water supply. This argument is not valid as it cannot be denied that the water quality is degraded to the extent that the concentration of impurities has been increased as a result of the depletion in flow in the water-course equal to the amount of water extracted for consumer use. Additionally, if any chemicals are used in the treatment process and are present in the filter washwater or sludge, they introduce new pollutants when discharged into water-courses. As federal, state, and local governmental agencies pass and enforce legislation to prohibit pollution of surface and underground water supplies, increasing numbers of treatment plants will be forced to abandon this simple and relatively inexpensive method of disposing of their sludge, filter backwash water, or brine.

Approaches to Waste Disposal

As a part of every study related to water treatment plant design, potential waste disposal problems should be investigated and suitable waste handling and process facilities included in the plans. In some instances, the cost of waste-disposal facilities may represent a very substantial part of the treatment-plant cost and may even influence the method of water treatment selected or the location of the plant site.

Several general approaches are suggested. Treatment processes may be selected or modified to produce a minimum of waste materials. Waste reclamation and water recovery processes should be evaluated for use. Means should be employed to produce the minimum quantities and most acceptable forms of residue requiring ultimate disposal. New methods and places for ultimate disposal of wastes should be investigated.

Characterization of Wastes

In order to indicate the bulk volume of sludge solids to be handled and the relative ability of these materials to be dewatered, sludges are often characterized by their settled solids concentration, filtering rate, and cake solids content. The sludge character is related to the raw water quality and the chemical-process scheme employed in treatment. Within a given plant, solids concentrations in settled sludges vary with the type of coagulant used, the turbidity, and with variations in the lime dose (where used).

The degree of dryness that must be obtained so that sludge can be handled by mechanical equipment varies from about 20 percent solids for dilute, clean-water coagulants to 50-60 percent for heavier sludges from hard, turbid waters. Often the transition from liquid to solid state appears to occur at solids concentrations between those obtained by draining and those obtained by filtering.

In general, settled iron sludges have a higher solids content than alum sludges, while the addition of polymer or lime increases the solids content of either. The presence of high magnesium levels in softening residues may cause deterioration in both the rate of settling and the degree of sludge compactibility.

Filter-backwash solids are always troublesome to handle. They are of low solids content even after thickening, and usually filter poorly. In some cases filter-backwash solids can be handled by decantation with the liquid going to the receiving waters and the solids going to sand drying beds. In other cases, the backwash water can be returned to the head of the plant at a uniform rate from storage, with the water being salvaged and the solids being mixed with incoming solids.

Minimizing Waste Quantities

Minimizing the quantity of waste produced during water treatment may be approached in several ways. Before selection of the treatment process, consideration should be given not only to the desired quality of the finished water but also to the quantity and nature of the wastes produced during treatment. For example, with the new and improved organic polymers available today, it may be possible to reduce or even eliminate the use of alum or other inorganic coagulants used for water clarification. In some instances, where raw-water quality permits, the application of minute dosages, 10-30 parts per billion (ppb), of a polyelectrolyte to the filter influent water may suffice to produce a good quality filtered water without the need for prior coagulation. In others, where coagulation is necessary, very low dosages, 0.2-3 parts per million (ppm), of the proper polyelectrolytes may effectively take the place of much larger dosages of alum or similar chemicals as the primary coagulant.

Substitution of polyelectrolytes for the more commonly used coagulants would reduce the weight and volume of the sludge produced and make it more amenable to dewatering. The weight and volume reductions would result from the use of a very small quantity of polyelectrolyte in place of a substantial quantity of inorganic polymer and also from the improved dewaterability of the sludge. In addition, the sludge would be more suitable for incineration because of the elimination of the noncombustible inorganic coagulants and the more complete removal of the water. These benefits will usually be reflected in a saving in operating costs for water and waste treatment despite the relatively high current prices of polyelectrolytes. Capital costs, too, may be lower due to reduced handling, storage, and feeding facilities associated with polymer use. Laboratory or pilot-plant tests are almost always necessary, however, to determine which polymer, or combination of polymers, is best suited for a particular raw-water quality and what dosages will provide effective and economical operation. A list of polymers approved by the EPA for use in treatment of potable waters appears periodically in the Journal of the American Water Works Association (AWWA) under the title, "Coagulant Aids for Water Treatment". The most recent additions to the list appear on page 735 of the November 1973 issue of the AWWA Journal.

Where softening is necessary in the treatment of hard waters, the means available and the costs for disposal of the wastes produced as well as water quality and costs of treatment chemicals should be considered. In coastal areas ion exchange may be more favorable because of the ease of disposal of spent brines into the oceans, and because substantial savings could result from the use of saltwater for regeneration of the exchanger. In inland areas, recovery, processing, or disposal of lime or lime-soda sludges may pose a lesser problem than would the disposal of brines from ion exchange. Hence the process should be designed to suit the location and the water treated.

Waste Stream Recycle

Processes are available for the recycling and reuse of alum, lime, and magnesium carbonate (but not for iron salts).

Alum may be reclaimed by either an acid or an alkaline process. The acid process consists of adding sufficient sulfuric acid to alum sludge to obtain pH values of 1 to 2. This redissolves the aluminum and the resulting solution is used as a coagulant for the raw water.

The insoluble inert waste solids can be separated from the recovered alum in a gravity settling step. By recovering the alum, the solids requiring ultimate disposal are significantly reduced and the remaining solids can be dewatered for ultimate disposal. Solids-liquid separation of the acidified sludge can be improved by use of the proper polymer. Filter pressing of the solids may produce 40-50% solids cake with 80-93% alum recovery. If iron and manganese are present in the alum sludge, they will be recovered along with the alum, necessitating a blowdown of some of the recovered alum to keep the iron and manganese content of the finished water within a satisfactory range.

If sodium aluminate proves to be a good coagulant for a particular water to be treated, then the alkaline method of alum recovery may be applicable. The aluminum can be redisolved from the alum sludge by raising the pH to 12-12.5 with sodium hydroxide. This converts the aluminum hydroxide to sodium aluminate, but also returns any phosphorus into solution. Calcium chloride is then added to precipitate the phosphorus. The insoluble phosphates can then be separated from the recovered sodium aluminate solution by a gravity settling step. The coagulant solution can be decanted off the top of the settling basin, and the phosphate sludge can be withdrawn from the bottom to a sand filter. The sand filter serves to recover additional coagulant and to act as a drying bed for the retained phosphate sludge which can later be removed for ultimate disposal. Alum recoveries of 90-95 percent are reported. An alternate alkaline recovery scheme uses lime in place of the sodium hydroxide and calcium chloride. However, alum recoveries by this means amount to only about 35 percent.

The recovery and reuse of lime is practiced both in water and in wastewater treatment. Settled lime sludge, which usually contains from 0.5 to 2.0 percent solids, is withdrawn from the clarifier to a gravity thickener where the solids content is increased to 8-20 percent. Optionally, the thickened sludge may be subjected to classification in a centrifuge. By proper control of the bowl speed, pool depth, and flow rate in the centrifuge it is possible to separate the heavier calcium from lighter inerts such as iron, magnesium, and phosphorus. Optimum operation of a centrifuge for classification purposes usually occurs at a solids capture of 70-75 percent, which corresponds to an increase of 12-15 percent of calcium in the cake. At 75 percent solids capture, it has been found that 90 percent of the phosphorus and 35 percent of the magnesium can be wasted in the centrate, with 87 percent of the usable lime being retained in the cake. The centrifuge cake contains about 40-55 percent solids. The cake can be recalcined in a suitable furnace. The furnace may be a multiple hearth, a fluidized bed, or an all electric (infra-red heat source). At furnace temperatures of 720-880C^{o} (1,600-1,900 degrees F), water and carbon dioxide are driven off from the dewatered sludge leaving only calcium oxide (quicklime) and inert solids (about 10-30 percent). The recalcined lime is then available for slaking and reuse in coagulation or softening of water. Solids wasting must be practiced continuously at a rate of about 25-30 percent in order to maintain an acceptable (more than 70 percent) calcium oxide content in the recalcined lime. If centrifugal classification is used (as previously described) as the means for ridding the recycle system of inerts, a second centrifuge may be used to dewater the centrate from the classification machine. The cake from the second machine contains the solids which are to be disposed of by incineration or by hauling to landfill. There are other ways to control the accumulation of inerts in the recalcined lime: (1) a portion of the thickener effluent can be wasted to a lagoon, (2) a single centrifuge may be used in a dewatering mode rather than as a classifier, with a portion of the cake being wasted to landfill or to an incinerator, (3) a portion of the recalcined lime containing inerts may be wasted, or (4) in some cases it may be possible to discharge a portion of the clarifier sludge directly to a sanitary sewer for subsequent use in a wastewater treatment plant.

Quite recently a new coagulant recovery technique has been developed. It is based on a combination of water softening and conventional coagulation procedures which can be applied to all types of waters. Magnesium carbonate is used as the coagulant with lime added to precipitate magnesium hydroxide as the active coagulant. The resulting sludge is composed of $CaCO_3$. $Mg(OH)_2$ plus the turbidity removed from the raw water. The sludge is then carbonated by injecting CO_2 gas which selectively dissolves the $Mg(OH)_2$. The carbonated sludge is then filtered, with the magnesium being recovered as soluble magnesium bicarbonate in the filtrate. The magnesium bicarbonate coagulant is then recycled to the point of chemical addition to the raw water where it is reprecipitated as $Mg\ (OH)_2$, and a new cycle is initiated. The filter cake produced in the separations step contains $CaCO_3$ and the turbidity removed from the raw water. In small plants this cake requires disposal.

In large plants it is feasible to extend the process with a further reduction in waste solids. The filter cake ($CaCO_3$ plus turbidity particles) is slurried and processed in a flotation unit to separate the turbidity particles from the $CaCO_3$. The purified $CaCO_3$ can then be dewatered and recalcined to high-quality quicklime for reuse in the process. The stack gases from the recalcining operation provide the CO_2 gas for carbonating the sludge in the magnesium recovery process and for recarbonating the water in the water treatment process. In large plants utilizing this lime and CO_2 recovery process, the only waste solids to be disposed of are those which were introduced to the plant as raw water turbidity.

Many waters contain enough magnesium that 100 percent magnesium recovery is achievable. With soft waters, magnesium recovery may be limited to about 80 percent.

Although it is possible to precipitate a very-high-purity carbonate and magnesium hydroxide from the spent brine from cation-exchange softening units, it is not a commercially practicable process. To recover these chemicals with any degree of efficiency it is necessary that the concentration of the brine be as high as possible. If the spent brine and subsequent rinse water are mixed prior to discharge, the mixture is too dilute to permit efficient precipitation of the calcium carbonate and magnesium hydroxide. Separation of the spent brine from the rinse water, on the other hand, is not very practical in an operating plant with many softening units. It is also questionable whether this recovery system would be economically competitive with other methods of producing pure calcium carbonate and magnesium hydroxide, even though it would leave a by-product of reusable brine. However, where conventional disposal costs are very high or pollution-control regulations are very restrictive, this recovery system may still warrant consideration.

Disposal Alternates

Disposal techniques for water treatment plant wastes include discharge to sanitary sewers, discharge to lagoons, land disposal, and sludge dewatering with ultimate disposal of residual wastes by barging to sea, in landfill, or by underground disposal. Any of these methods may require a local or federal permit such as that required by the Marine Protection, Research, and Sanctuaries Act.

The discharge of water treatment plant wastes to a sanitary sewer may have either beneficial or detrimental effects on subsequent sewage treatment, depending upon the type of water plant sludge discharged and the sewage treatment processes used. Where discharge of water treatment plant wastes to sanitary sewers is feasible, this alternate should be investigated, as it may be better and cheaper overall than separate processing at the water plant site. In addition, under some circumstances, the cost of sewage treatment may be reduced or improved treatment obtained. It is reported in some cases that water purification plant sludges improve overall sewage treatment plant performance, particularly the removal of chemical oxygen demand, and in better settling of waste activated sludge.

In considering the discharge of water purification sludges to lagoons, one factor to weigh is that the sludge may not be suited for mechanical handling even after it is completely drained. Where disposal methods other than direct discharge into a lake or watercourse are used, lagooning ranks high in popularity, particularly for lime sludges. It is probable that lagoons will be used for disposal of water-treatment plant sludges as long as land areas remain available for this purpose. Lagoons should be impermeable.

Four factors govern the size of a lagoon required for treatment-plant sludge: (1) the volume of liquid sludge to be handled; (2) the quantity of dry solids produced after removal of the supernatant water and compaction of the residue; (3) the rate of evaporation in the locality; and (4) the frequency of cleaning desired.

Land Disposal

Liquid sludge may be hauled to agricultural land when the solids do not exceed 10 to 12 percent by weight. Trucking of wet sludge to agricultural lands or disposal areas requires proper handling, vehicles, and equipment to permit handling and spreading without creation of nuisances. It is necessary to provide sludge handling facilities for use during times that trucks cannot operate.

Disposal of water-treatment plant sludges to landfill operations has shown an increase; this practice will probably continue and even expand, unless reclamation and processing for salable by-products become much more popular than they are. If not recalcined to recover lime, the softening-plant sludge can be dewatered by centrifuge, vacuum filter, filter press, or drying beds to make it more suitable for road bed stabilization, soil conditioning, or neutralization of acid wastes in industry.

Ultimate Disposal of Residuals

If processing of wastes to recover treatment chemicals or useful by-products is not feasible, then processing to produce the most acceptable forms and minimal quantities for ultimate disposal should be the goal. In the preceding section reference was made to dewatering of sludges to enhance their usefulness in industrial or agricultural operations. If final disposal of the sludge is to be in a sanitary landfill, prior dewatering will make it easier to haul and to handle in the mixing operation.

Lime sludges can be dewatered quite effectively (to about 50 percent solids) within a reasonable time on drying beds and, if sufficient area is available and the climate favorable, it can be an economical procedure. Alum sludges, on the other hand, are far more difficult to dewater in this manner. Filling depths are usually limited to less than 0.61 meters (2 feet) to permit cracking and drying to the bottom of the cake. Under very favorable climatic conditions, the alum sludge cake will dry to about 25-30 percent solids overall, the top being drier than the bottom.

Dewatering by vacuum filtration has worked successfully with lime sludges. Crumbly cake with a solids content up to 65 percent has been obtained with this type of equipment. Vacuum drum filters have also been used to dewater alum sludges but with less success than with lime sludges. The only semicontinuous equipment that has dewatered alum sludges effectively is the rotary-vacuum precoat filter. The precoat of diatomaceous earth (DE) prevents the aluminum hydroxide from binding the septum, holds the sludge solids on the surface of the drum from which they are removed by a slowly advancing knife as the drum rotates, and helps to produce a clear filtrate. In pilot studies, the solids content of the cake produced has exceeded 30 percent. Approximately one quarter to one third or more of the cake consists of the DE filter aid used, depending upon the concentration of the sludge filtered. Preconditioning of the alum sludge with lime is also desirable to improve the filter-ability of the sludge.

When lime sludge is dewatered prior to calcination, centrifuging is generally used as it performs the important function of separating the magnesium hydroxide as well as the water from the calcium carbonate. Sludge cake with solids up to 70 percent can be obtained if the ratio of calcium to magnesium is high in the sludge feed. Again, centrifuging of alum sludges is more difficult and less satisfactory than with lime sludges.

In the U.S., filter presses have not been used to any great extent for dewatering water-treatment-plant sludges, but they have found wider acceptance in Europe and the Orient. As with the other methods described, the more granular lime sludge is dewatered more quickly and more completely by the filter press than is alum sludge. To work effectively for long periods, the filter cloth in the press must receive a precoat of ash or diatomaceous earth just as the vacuum filter does when alum sludge is to be filtered, and preconditioning of the sludge plus a body feed of ash or diatomaceous earth are both necessary for efficient operation. High pressures permit production of a sludge cake with a greater solids content than can be obtained by other methods, and recent improvements in the presses and filter media may lead to greater use of this type of dewatering equipment in the future.

In addition to earning an important place in the coagulation of waters and in the improvement of filter performance, polyelectrolytes appear to offer a new and better way of conditioning sludges to assist in the dewatering operation. They may prove to be the means for attaining higher efficiencies in the operation of the dewatering equipment described.

Freezing and thawing show promise as a method of dewatering and reducing the volume of alum sludge. In this process, which is irreversible, the alum sludge first is thickened to a solids concentration of about 3.5-4 percent, and then frozen slowly and completely. The ice crystals formed during freezing squeeze the water from the sludge and compress the particles to about one sixth of their original volume. When thawed, they are like a brown powder or sand. In areas where winter temperatures permit natural freezing, this process should prove attractive and economical for conditioning and concentrating alum sludges. Even artificial freezing, although much more costly, may warrant consideration, particularly if a market can be found for the sludge granules.

Sludge incineration can now meet the stringent requirements of air-pollution control agencies and may offer a way to reduce very substantially the bulk of some water-treatment-plant sludges - although, even with more efficient incinerators, combustion of alum sludges may not be feasible because of their high moisture content and low ratio of combustibles. Polyelectrolyte sludges will lend themselves much more readily to incineration. With the low dosage of polyelectrolyte required for coagulation, the percentage of combustible organic matter in the sludge should normally be relatively high. Additionally, since the polyelectrolyte sludges can be dewatered more completely than alum sludges, the amount of water introduced to absorb heat energy during incineration should be much lower, leading to more economical operation. The ash remaining after incineration will represent only a minute fraction of the volume occupied by the original sludge.

Some water-treatment plants located near the coast have gone so far as to barge their sludge 200 miles out to sea for ultimate disposal, which in such cases may be the most economical way to avoid a potential pollution problem. Where permissible, introduction of the sludge into the outfall of a sewer is recommended. Plants within reasonable hauling distances of deserts or other barren areas may be faced with the need to transport sludges by rail or truck to such disposal sites. If abandoned mines or subterranean caverns are not too far from the water-treatment plant, they too may be available for ultimate disposal of sludges.

Good engineering information and cost data on sludge handling is given in the EPA Technology Transfer Publication entitled, "Process Design Manual for Sludge Treatment and Disposal", EPA 625/1-74-006, October 1974.

As the practice of wastewater reclamation and reuse gains increasing acceptance in the future, it is probable that discharge of softening plant regenerant brines into municipal sewer systems will be markedly curtailed, and alternatives should be considered. In areas within reasonable distance of the oceans or other large bodies of saline water, brine-discharge lines could be built from the water plants to these natural disposal sites to provide a very simple and relatively economical means for waste brine disposal. Other alternatives for plants not so fortunately located and still desirous of using ion-exchange softening are: (1) Evaporating basins or brine-disposal wells (where there is no possibility of intrusion into a fresh-water aquifer) and (2) controlled discharge into a watercourse, if a permit can be obtained with reasonable expectancy of continued renewal.

Summary

In summary, insofar as process design and plant operations are concerned, the need is to explore all possible means of (1) minimizing the quantities of wastes produced; (2) recovering chemicals and water from the waste products; (3) processing wastes to produce useful by-products; (4) processing wastes to improve the character and reduce the quantity of residue left for final disposal; and (5) disposing of the irreducible residue in a manner that will not degrade the environment.

Miscellaneous Plant Wastes

Provisions should also be made in water treatment plants for satisfactory disposal of sanitary and laboratory wastes. Waste waters from water main disinfection must be disposed of satisfactorily.

Environmental and Economic Impacts

The method selected for disposal of plant wastes should be considered in the light of its environmental and economic impact.

1.7.0 Uses of New Processes or Equipment

Policy

New methods and equipment for the treatment of water are encouraged. However, any new developments should be thoroughly tested under competent supervision, before approval is issued for a plant utilizing a new process or equipment. Pending the development of satisfactory performance data, no new water treatment processes or materials of construction will be accepted unless the designing engineer can present conclusive evidence that his plans provide for effective use of the processes to treat the specific supply involved, so as to insure the delivery of water of safe sanitary quality and satisfactory mineral quality without imposing undue problems of supervision, operation, and control.

New Process Studies

New process studies for water treatment shall be made when the proposed process is outside the scope and requirements of this manual, or when a proposed treatment process includes unproven equipment or unproven chemical additives.

New-process studies will be either a pilot facility discharging its treated water to waste, or a partial-or full-scale evaluation of a process in an existing water plant. If an inplant evaluation is done, it must be with the understanding that all water produced will be wasted if satisfactory finished water quality is not obtained during any portion of the evaluation test run.

Procedure

The procedure for the design engineer to follow in proposing a new process study is to submit a description of the operating sequence to be tested and the format of the data to be collected to the State. The proposal shall also include: a raw water analysis of source water for all parameters in the Federal Drinking Water Standards; a historical record of pertinent raw water analyses, if available; a complete outline of investigative intent, concerns, and limitations; and a list of chemicals to be used and the anticipated dosage rates.

Upon completion of the tests, the engineer shall submit a report to the State on the results of the special study, at design flow rates and at overload. To qualify for approval, the results must conclusively demonstrate that the proposed processes, equipment, or chemicals will produce water equal to or better than that required by Federal Drinking Water Standards.

SECTION II SOURCE DEVELOPMENT

2.1.0 General

In selecting the source of water to be developed, the designing engineer should prove to the satisfaction of the State that after the proposed treatment the water which is to be delivered to the consumers will meet the Federal Drinking Water Standards in all respects including bacteriological, physical, chemical, and radiological qualities.

Where water sources show continuing quality deterioration or where the quality of water available is not adequate for future demand, the water purveyor should examine alternate or auxiliary sources of supply and should have positive plans to procure adequate facilities and sources.

SUMMARY OF DESIGN STANDARDS - SOURCE DEVELOPMENT

2.2.0 Quantity and Quality

2.2.1 Design Period for Surface Supply Works(II-21)(I-3)

For major impoundments and long raw water transmission lines which require difficult planning, construction, property acquisition, and financing and which are not amenable to phased construction, the design period should be on the order of 50 years. For intake works, pump stations, and pipelines whose capacity can be increased without too much difficulty, a shorter period such as 20 years may be suitable.

2.2.2 Design Period for Ground Water Supplies(II-21)

For centralized major well fields and long transmission lines which require difficult planning, construction, property acquisition, and financing and which are not suited to staged construction the design period should be on the order of 50 years. For development of scattered wells or other ground water supplies which can be constructed in stages without excessive added costs, a shorter design period of 10 to 20 years may be appropriate. Well sites should be available and identified to assure continued supply based on projected needs.

2.2.3 Quality of Water From Surface Source(I-3)(I-30)

Provide water for maximum daily demand during design period, with sufficient finished water storage at the treatment plant or on the distribution system to meet peak hourly demands plus fire fighting requirements (see Section VI).

Preceding page blank

2.2.4 Quantity of Water From Well Water Supplies(I-3)(I-30)(VII-3)

Provide either: (1) water for maximum daily demand during design period with adequate storage or distribution system to meet peak hourly demands and fire fighting requirements, or (2) in the absence of sufficient storage to meet peak hourly demands and fire flows, enough well capacity to meet these requirements for the design period, (see Section VI).

2.2.5 Safe Yield for Flowing Streams(I-60)

Where water is drawn from a flowing stream, the minimum stream flow of record, less water demand of other users, or the minimum stream flow of record, less water demand of other users, plus water available from side storage, should exceed the estimated future water demand on the maximum day, (including fire requirements).

2.2.6 Safe Yield for Reservoirs and Lakes(I-60)

Where water is drawn from an impounding reservoir or lake, the average inflow for the driest period of record, and the effective storage capacity of such a reservoir or lake, should exceed the estimated future demand for the maximum drouth period of record (or the projected 100 year drouth). The effective storage capacity shall take into account evaporation, seepage and siltation losses.

2.2.7 Safe Yield From Wells(II-4)

The "safe yield" of each well shall be estimated taking into account the results of pumping tests, well location and construction, and the minimum static water level and rate of ground water reservoir replenishment during the driest period of record. The quantity of water available from all wells shall comply with requirements of Section 2.2.4

2.2.8 Federal Drinking Water Standards(II-71)(II-72)

The Federal Drinking Water Standards referred to in this Manual are the latest effective regulations as established under Public Law 93-523, The Safe Drinking Water Act.

The latest Federal Drinking Water Standards are, or will be, available as a separate document from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Reference to the Federal Drinking Water Standards is necessary for full understanding and use of this Manual.

2.2.9 General Treatment Requirements(II-18)(II-8)(II-9)

The water quality requirements of the Federal Drinking Water Standards are minimum requirements, and good quality water should have physical and chemical characteristics considerably better than the limiting values established in the Federal Drinking Water Standards. (II-1)

The type of treatment required depends on the characteristics of the watershed, the raw water quality, and the desired finished water quality. If pollution of the source water is increasing, plant facilities which were adequate for treatment of a nonpolluted water may become inadequate.

The production of water that is free from pathogenic organisms, aesthetically satisfactory to the senses, and reasonably acceptable chemically becomes increasingly difficult when the raw water has a high and varying chlorine demand, contains large numbers of coliform bacteria, or contains high concentrations of dissolved solids, toxic substances, or taste and odor producing substances.

When evaluating the ability of a water supply system to constantly produce a safe and satisfactory water, these factors should be considered:

(a) the quality of water produced at times of unusual stress, such as during heavy run-offs, periods of drought, periods of excessive demand, or a combination thereof as shown in the records; (see Section IX).

(b) the quality of the raw and finished waters, as determined by laboratory data and sanitary surveys, and any trends toward improvement or deterioration; (see Section IX).

(c) the purification processes, including the facilities used to apply disinfectants at various locations in the treatment process, and their capacities compared with the capacities considered necessary to meet maximum anticipated requirements; (see Section III).

(d) the treatment processes used and their reliability in changing raw water characteristics to produce a finished water that continuously meets the Federal Drinking Water Standards; (see Section III).

(e) the minimum residual chlorine concentration in the plant effluent water, when chlorine is used, together with the time that this or greater chlorine levels were maintained;

(f) the qualifications of the operators and laboratory personnel, as indicated by appropriate training, or certification, or both; (see Section X), and

(g) the laboratory facilities and analytical procedures, frequency and extent of their use, and application of the data to operational control, (see Section VIII and IX).

All public water supplies, whether they be ground water or surface water should receive treatment by disinfection regardless of the quality of the water. The benefits from the added protection provided by disinfection far outweigh the increased cost and the added maintenance incurred by the water utility. When coliform density is used as one criterion for judging treatment requirements, raw waters can be divided into three groups: clean, clear, and polluted waters. The coliform densities of the raw waters can be expressed in terms of the most probably number (MPN) from the multiple-tube fermentation technique, or actual coliform counts determined by the membrane filter (MF) technique.

Treatment requirements are given for three groups of water according to bacterial content.

2.2.10 Bacteriological Quality Versus Treatment Requirements (II-18)(II-69)(II-63)(II-64)

The utility shall provide adequate treatment which will assure a high degree of reliability in effecting compliance with the Federal Drinking Water Standards. In general, as a minimum, this requires disinfection of all waters, and, in addition, coagulation, with or without settling, and filtration or equivalent for all surface waters. If the water purveyor has data acceptable to the State indicating that the produced water will consistently meet the Federal Drinking Water Standards, the above requirements for treatment may be reduced as determined by the State.

2.2.10.1 Low Coliform Waters

Underground waters (only) containing not more than 100 coliform bacteria (M.P.N.) per 100 ml as measured by the monthly arithmetic mean, and having a standard plate count limit of 500 organisms per ml, a fecal coliform density of less than 20 per 100 ml as measured by a monthly arithmetic mean, and meeting in other respects the Federal Drinking Water Standards should be subjected to continuous disinfection treatment. At least 30 minutes contact with the disinfectant before discharge of the water into the distribution system is highly recommended.

2.2.10.2 Moderate Coliform Waters

Waters containing not more than 5,000 coliform bacteria (M.P.N.) per 100 ml. and meeting in other respects the Federal Drinking Water Standards should be treated by coagulation with or without settling, filtration, and continuous post-disinfection with 30 minutes or more contact with the treated water before use. For waters in this class, pre-disinfection with at least 30 minutes contact at a pH under 7.5 is strongly recommended.

2.2.10.3 High Coliform Waters

Waters containing not more than 20,000 coliform bacteria (M.P.N.) per 100 ml as measured by a monthly geometric mean and meeting in other respects the Federal Drinking Water Standards should be subjected to pre-disinfection and a minimum of 30 minutes contact at a pH under 7.5, followed by mixing, flocculation, settling, filtration, and post-disinfection.

2.2.10.4 Excessively High Coliform Waters

Waters containing more than 20,000 coliform bacteria per 100 ml or having a fecal coliform count exceeding 2,000 per 100 ml monthly geometric mean are considered undesirable as a source of supply.

In the absence of an adequate supply of water of better bacteriological quality, special methods of treatment may be considered. Proposed special methods of treatment for highly polluted waters should be approved by the State prior to the preparation of plans.

2.2.10.5 Wastewater Reuse

The EPA Policy Statement on Water Reuse is as follows:

"The demand for water is increasing both through population growth and changing life styles brought about by advancing technology, while the supply of water from nature remains basically constant from year to year. This not to imply that we are or will shortly be out of water, although water shortages are of great concern in some regions. Rather, we must recognize the need to use and reuse wastewater whenever possible. Therefore,

(1) EPA supports and encourages the development and practices of successive wastewater reclamation, reuse, recycling, and recharge as a major element in water quality management, providing the reclamation systems are designed and operated so as to avoid health hazards to the people or damage to the environment.

(2) EPA recognizes and supports the potential for wastewater reuse in agriculture, industrial, municipal, recreational, and groundwater recharge applications.

(3) EPA does not support the direct interconnection of wastewater reclamation plants with municipal water treatment plants.

(4) EPA will continue to support reuse research and demonstration projects."

(II-71)(II-72)

2.2.11 Chemical and Physical Quality Versus Treatment Requirements

Drinking water should contain no impurities that would cause offense to the sense of sight, taste, or smell. Drinking water should not contain impurities in concentrations that may be hazardous to the health of the consumer. It should not be excessively corrosive to the water supply system. Substances used in water treatment should not remain in the water in concentrations greater than required by good practice. Substances that may have deleterious physiological effect or for which physiological effects are not known, should not be used in a manner that would permit them to reach the consumer.

The following chemical and physical constituents are limited either by the 1962 USPHS Drinking Water Standards or the EPA Interim Primary Drinking Water Standards of March 14, 1975, as applicable, and should not be present in water served to consumers in excess of the amounts indicated. These limits may be changed by updated standards promulgated in the future. In certain cases, raw waters not conforming to the requirements for chemical and physical quality can be treated to reduce the concentrations within allowable limits. General methods for treatment and other remedial measures are presented in the Rationale for Source Development which follows. More detailed data on water treatment methods are given in Section III of this Manual.

2.2.11.1 Maximum Contaminant Levels For Inorganic Chemicals

(a) The following are the maximum contaminant levels for inorganic chemicals (for health reasons):

Contaminant	Level,mg/l
Arsenic	0.05
Barium	1.0
Cadmium	0.010
Chromium	0.05
Cyanide	0.2
Lead	0.05
Mercury	0.002
Nitrate (as N)	10.0
Selenium	0.01
Silver	0.05

(b) When the annual average of the maximum daily air temperatures for the location in which the public water system is situated is the following, the corresponding concentration of fluoride shall not be exceeded.

Temperature (in F^{o})	c^{o}	Level, mg/l
50.0 to 53.7	10.0 to 12.0	2.4
53.8 to 58.3	12.1 to 14.6	2.2
58.4 to 63.8	14.7 to 17.6	2.0
63.9 to 70.6	17.7 to 21.4	1.8
70.7 to 79.2	21.5 to 26.2	1.6
79.3 to 90.5	26.3 to 32.5	1.4

The requirements of this paragraph (b) do not apply to public water supplies serving only educational institutions.

2.2.11.2 Maximum Contaminant Levels For Organic Chemicals (II-72)

The maximum contaminant level for the total concentration of organic chemicals as determined by the carbon-chloroform Extract method (CCE-m) is 0.7 mg/l (for health reasons).

The sampling and analyses to determine compliance shall be made in accordance with "An Improved Method for Determining Organics in Water by Activated Carbon Adsorption and Solvent Extraction", Parts 1 and 2, JAWWA, 65:57, 197 (1973).

2.2.11.3 Maximum Contaminant Level For Pesticides (II-72)

The following are the maximum contaminant levels for pesticides (for health reasons):

(a) Chlorinated Hydrocarbons	Level mg/l
Chlordane (cis and trans) (1,2,4,5,6,7,8,8-Octochloro-3a, 4,5,7a-tetrahydro-4,7-methanoindan)	0.003
Endrin(1,2,3,4,10,10-Hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo, endo-5-8-dimethano naphthalene)	0.0002
Heptachlor (1,4,5,6,7,8,8-Heptachloro-3a,4,7,7a-tetrahydro 4,7 methanoindene)	0.0001
Heptachlor Eposide (1,4,5,6,7,8,8-Heptachloro-2,3-epoxy-3a,4,7,7a-tetrahydro-4,7-methanoindan)	0.0001

Lindane (1,2,3,4,5,6,-Hexachloro-cyclohexane, gamma isomer)	0.004
Methoxychlor (1,1,1-Trichloro-2,2-bis [p-methoxyphenol] ethane)	0.1
Toxaphene ($C_{10}H_{10}Cl_8$-Technical chlorinated camphene, 67-69% chlorine)	0.005

(b) Chlorophenoxys	Level mg/l
2,4-D (2,4 Dichlorophenoxy acetic acid)	0.1
2,4,5-TP Silvex (2,4,5-Trichlorophenoxy propionic acid)	0.01

2.2.11.4 Maximum Contaminant Level of Turbidity (II-72)

The maximum contaminent level of turbidity in the drinking water (for health reasons) at a representative entry point (s) to the distribution system is one turbidity unit (TU), except that five or fewer TU may be allowed if the supplier of water can demonstrate to the State that the higher turbidity does not:

(a) Interfere with disinfection;

(b) Prevent maintenance of an effective disinfectant agent throughout the distribution system; and

(c) Interfere with microbiological determinations.

2.2.11.5 Odor and Color(II-71)

Water having a Threshold Odor number greater than 3 or a color greater than 15 color units is objectionable esthetically to a considerable number of people.

2.2.11.6 Foaming Agents(II-71)

For esthetic reasons the maximum allowable limit of these substances measured as methylene-blue active substances (MBAS) is 0.5 mg/l.

2.2.11.7 Iron and Manganese(II-71)

Iron concentrations in excess of 0.3 mg/l and manganese content greater than 0.05 mg/l in water stain laundry and plumbing fixtures and impair the taste of coffee, tea, and other beverages.

2.2.11.8 Copper, Zinc, and Hydrogen Sulfide(II-71)

The presence in water of copper in excess of 1 mg/l, zinc in the excess of 5 mg/l, or hydrogen sulfide in excess of 0.2 mg/l is esthetically objectionable.

2.2.11.9 Chlorides and Sulfates(II-71)

Chlorides or sulfates at levels greater than 250 mg/l in water are esthetically unacceptable.

2.2.11.10 Sodium(II-17)

No limit designated, but the water utility should periodically notify local physicians of the sodium content of the public water supply so that they may advise their patients of suitable dietary restrictions.

2.2.11.11 Radioactivity(II-71)

Approval limits (Health) for finished drinking water cannot be based on an assumed harmless level of radiation dose. Rather, controls for both individual and population exposures should be based on the prudent assumption that there is no threshold dose for damage from ionizing radiation and that any health effects will be proportional to the dose delivered by the ingested activity.

Since the absence of health effects cannot be assumed, the radiological quality of water must meet two criteria. Not only must the risk to individuals using the water supply be small but also the total health impact on the population using the water supply system must be limited, a criterion best met by considering the sum of all the individual doses received by those persons using the supply. This aggregate dose, in units of man-rems or organ-rems is computed by multiplying the number of persons using the supply by the average annual total body or organ dose an individual receives by ingesting the water. A numerical example of an aggregate dose calculation is given in this Section under Rationale for Source Development.

(a) Radium-226, other alpha particle emitters, and Radium-228.
Approval Limit (Health)
Aggregate dose limit to the population served by any water supply system shall not exceed -

3000 organ-rem/yr. In no case, however, shall the average annual concentration be greater than:

Radium-226 and/or Radium-228 - 5 pCi/l
Gross alpha particle activity* (including Radium-226) - 15 pCi/l.

*Corrected for the contribution, if any, due to radon and uranium.

(b) Beta particle and photon activity from artificial radionuclides.

Approval Limit (Health)
Aggregate dose limit for the population served by any water supply system shall not exceed - 15,000 man-rem/yr. In no case, however, shall concentration produce in any individual a yearly dose to the total body or any internal organ greater than - 0.015 rem/yr.

2.2.11.12 Asbestos. No limit established; see Rationale 2.2.11.12.

2.3.0 Surface Water

2.3.1 River Intakes(I-30)

In selecting location consider channel changes, navigation requirements, water depth, trash, ice, 100 year flood level, water velocity, silting, separation from pollution sources, possibility of shoal or bar formation, water quality effects due to wind and waves, and access. Also evaluate quantity of supply, cost of development versus alternate locations and sources, and possible need for storage dam, either in-channel, or off-channel.

2.3.2 Impoundments

2.3.2.1 Site Selection(I-30)

Consider topography, storage capacity versus dam and spillway required, geology, safety, and water rights.

2.3.2.2 Sanitary Survey(I-64)(II-18) - the following items should be included: catchment area: size, topography; population density, sewered and unsewered; surface geology; reservoirs, their capacity and location, swamps, marshes, land use, soil erosion.

Sources of pollution: nature; distance from intake, including miles and rate of flow; amounts and distances of sewered population.

Sewage treatment on watershed: Extent; methods; population served; effectiveness and uniformity of results.

Raw-water characteristics: Turbidity, color, alkalinity, hardness, iron, etc.; bacterial quality, average and ranges; variations in quality, especially after heavy rainfall or at times of high run-off.

Proximity of sources of fecal pollution to intake of water supply.

Proximity, sources and character of industrial wastes, oilfield brines, acid mine waters, etc.

Character of vegetation; forests; cultivated and irrigated land, including salinity, effect of irrigation water, etc.

Detention in storage.

Factors affecting time of travel of pollution from its source to the water supply source.

2.3.2.3 Preparation of Site(I-30)

Site preparation should include removal of brush and trees to high water elevation and protection from floods during construction.

2.3.2.4 Protection of Source(I-30)(II-18)(II-64)

Consider provisions, as may be necessary, for: regulating wastewater treatment and disposal, recreational activities, erosion, pasturage of animals, clearing timber, spills of hazardous materials, mosquito control, ice cutting, land use, and other factors which could effect water quality or safety.

2.3.2.5 Recreational Use Effects(II-18)

Bathing, water skiing, boating, fishing, or other activities in or on any water used as a source of water supply should be conducted in a manner that the water quality will not be adversely affected as a source of water supply by these activities.

2.3.2.6 Mixing or Aeration

Consider need for reservoir turnover or aeration system to prevent stratification of dissolved oxygen and temperature, to prevent solution of iron and manganese, and to prevent complete ice cover and oxygen depletion.

2.3.2.7 Selection of Depth of Withdrawal(I-30)

When the quality of a surface water varies at different depths an intake structure which will permit withdrawal of water from more than one level should be provided.

2.3.2.8 Evaporation, Seepage, and Siltation

Provisions should be made to minimize losses due to these items. See Rationale for Source Development.

2.3.3 Structures(I-30)

2.3.3.1 Dams and Spillways

Approval of safety features for stability and spillway design of any structures should be obtained from appropriate reviewing authority.

Permit for controlling stream flow or structure on bed of navigable stream or interstate water, to be obtained from appropriate reviewing authority.

2.3.3.2 Intakes(I-30)

Intake structures shall provide for:

Sufficient capacity to supply treatment plant flow requirements with due consideration to operation under minimum head conditions.

Velocity of flow through inlet structure such that frazil ice will be held to a minimum, .075 to .15 meters per second (0.25 to 0.50 fps). Air bubbler systems are one consideration to keep intakes free of ice.

Location in areas not subject to excessive siltation and areas not subject to receiving immediate runoff from wooded sloughs and swamps.

Location to minimize the entrance of debris. To divert surface debris, a floating logboom or other effective device should be used around the intake structure.

Inlets or gates shall be located in the structure so that water may be admitted from a choice of depths and to permit location to be easily identified through permanent monuments on structures. A choice of at least three depths should be provided in impoundments or reservoirs. Withdrawal of water from more than one level may be desirable in run-of-the-stream intakes if the quality varies with depth. The lowest inlet or gate should be placed at an elevation where it will be entirely submerged at all water stages.

Separate facilities for release of less desirable water held in storage.

Screens and grates to minimize the amount of debris entering the plant. Screens should be cleaned regularly.

Prevention of flooding of access walkways and control valves of intakes on multiple purpose reservoirs.

Adequate protection against rupture by dragging anchors, ice, etc.

Inspection manholes every 305 meters (1,000 feet) for pipe sizes large enough to permit visual inspection, 20 cm (8 inch) diameter or larger.

No public boat launching ramps, marinas, docks and floating fishing piers should be located within 305 meters (1,000 feet) of the raw water intake.

2.3.3.3 Shore Wells(I-30)

Shore well intakes should:

Have motors and electrical controls located above grade and preferably above 100 year flood level,

be accessible,

be designed against flotation,

be equipped with removable or traveling screens before pump suction well,

provide disinfection facilities for raw water transmission main if necessary for quality control, and

have intake valved and provisions for backflushing and testing for leaks, where practical.

Off Channel Reservoirs

An off channel reservoir development should assure that:

water quality is protected by controlling runoff into this reservoir,

dikes are structurally sound and protected against wind action and erosion, and point of influent flow is separated from the point of withdrawal.

Raw Water Pumping Stations

Each pumping station should be so designed, constructed, and equipped that it can deliver the water from the point of intake to the point of discharge without impairment of its sanitary quality, and in such quantities, at such time, and at such pressures as are necessary. They should be designed for simplicity of operation by non-technical operators and to not require continuous attendance. Standard equipment should, insofar as possible, be used for economical operation and maintenance and quick procurement of repair parts in an emergency.

2.4.0 Ground Water

2.4.1 Sources of Ground Water(I-30)

Groundwater includes water from dug, drilled, bored or driven wells, springs, and infilration galleries. Wells are preferred, and springs and infiltration galleries should be utilized only where geological conditions preclude the probability of developing a satisfactory drilled well source, (see Section 2.2).

2.4.2 Location and Protection(I-18)

Ground water sources should be located, constructed and maintained in a manner which will assure the minimum possibility of contamination and be so situated and developed as to prevent surface water from entering the well or spring. To assure adequate sanitary control in the vicinity of the source, the purveyor should control all land within a radius of one hundred feet of the well or spring and any additional land as may be determined necessary by the State. The total required control area should be based upon an evaluation of construction details; and geological and hydrological factors.

2.4.2.1 Sewers and Septic Tanks (I-18)

To avoid contamination of source, any sewer or line carrying sanitary or industrial wastes which is within 30.5 meters (100 feet) of a ground water source should be of steel, reinforced concrete, cast-iron or other suitable material; should be properly protected, of completely watertight construction, and should be tested for watertightness after installation.

No manholes or connections on a sanitary sewer system should be permitted within 30.5 meters (100 feet) of a ground water source. A well or spring should not be located less than 15.2 meters (50 feet) from a septic tank, or less than 30.5 meters (one hundred feet) from a septic tank absorption field, or less than 3.05 meters (10 feet) from a sewer. Greater distances from septic tank systems and sewers may be required at the discretion of the State due to topography, local soil or geological conditions.

2.4.2.2 Sanitary Surveys(I-18)

Sanitary surveys made for selection of locations for wells, springs, or infiltration galleries should consider the following items:

(a) Character of local geology; size and topography of catchment area; slope of ground surface.

(b) Nature of soil and underlying porous strata-whether clay, sand, gravel, rock (especially porous limestone); coarseness of sand or gravel; thickness of waterbearing stratum; depth to water table, location and log of wells in vicinity in use and/or abandoned.

(c) Slope of water table, preferably as determined from observation wells, or studies of wells in the area.

(d) Extent of drainage area likely to contribute water to the supply; population on, and waste disposal methods in the drainage area.

(e) Nature, distance, and direction of local sources of pollution such as animal feed lots, dumpgrounds, sanitary landfills, seepage pits, soil absorption fields, privies, sink holes, dumping areas, caves, test holes, abandoned wells, borings, and industrial lagoons.

(f) Possibility of surface-drainage water and salt or brine supply, and of wells becoming flooded; methods of protection.

(g) Methods used for protecting the supply against pollution, by means of sewage treatment, waste disposal, and the like.

(h) Type of construction employed and the protection it affords against pollution of the water source.

(i) Water obtained from springs, infiltration galleries, wells in fissured areas and/or any other source subject to surface or near surface contamination of recent origin shall be evaluated for the provision of treatment facilities, in addition to disinfection.

(j) The extent of water treatment required will be determined on the basis of geological data, well construction features, nearby sources of contamination and perhaps on the basis of quantitative bacteriological and chemical analyses.

(k) Where a well draws water from the creviced limestone strata and it is evident that the limestone supply is contaminated, use of the limestone water cannot be considered satisfactory unless it is properly treated for elimination of harmful organisms by coagulation, filtration, and disinfection.

(l) 100 year flood waters should not approach closer than 15 meters (50 ft.) horizontally to the well of spring.

(m) The well or spring should not be located in a ravine where the site may be flooded by impounded or accumulated water.

(n) The location of ground water supplies on a hillside or at the foot of a hill where privies, cesspools, sewers or other sources of pollution are located on the slope above and within 91.4 meters (300 feet) horizontally, should be avoided.

(o) The pump room floor shall be at least 0.6 meters (two feet) above the highest known water level of any nearby body of surface water.

(p) Proximity to gasoline stations, storage tanks, and plants should be avoided.

(q) The raw ground water should be of such quality that by providing reasonable water treatment facilities, the finished water will meet the Federal Drinking Water Standards.

(r) Livestock in pastures should not be allowed within 15 meters (50 ft.) of water supply wells and springs.

2.4.3 Infiltration Galleries(I-30)

There is no well-defined distinction between a well constructed near the shore line of a lake, pond, or river and an infiltration gallery. Generally speaking, a well, even though it may be near the shore line of a body of surface water, collects only ground water. Under these circumstances the elevation of the ground water in the well exceeds that of the body of surface water nearby. If, however, water is pumped from a well at such a rate that the water table is lowered below the level of the surface water and a reversal in the direction of flow occurs, the structure would be termed an infiltration gallery. Under these circumstances the quality of the water in the nearby stream, lake, etc., and the effectiveness of filtration afforded by the intervening soil between the infiltration gallery and the bed of the pond or stream is of paramount importance. The quality of water secured from infiltration galleries, therefore, depends on the rate of percolation of the water and the filtering ability of the soil.

Ordinarily infiltration galleries should be located at least 15 meters (50 ft.) from the shore line of bodies of surfaced water. although a lesser distance may provide effective clarification of the surface water as it percolates toward the gallery. Disinfection is still recommended to remove bacterial pollution. The natural filtration of the surface water tributary to an infiltration gallery materially improves the physical character of the water and thus purification may be restricted to disinfection rather than artificial filtration and disinfection. For this reason, infiltration galleries provide economical means of securing clear water when available surface water is turbid and when adequate quantities of ground water are not available. The feasibility of using such galleries should be investigated before intakes are constructed in streams, lakes, ponds, etc., where considerable pollution is present, or where the water is colored, turbid, or supports a growth of algae.

Gravity flow to collection wells is recommended.

Avoid use of open trenches due to problems of algae, erosion, and surface contamination.

Design velocity in flow in buried collecting pipes should not exceed 0.6 meters (2 feet) per second.

Valves should be placed at ends of collection pipes, and provisions made for backflushing and repairs.

Radial Water Collector

(a) location of all caisson construction joints and porthole assemblies should be indicated on plans.

(b) caisson wall should be substantially reinforced;

(c) radial collectors should be in areas and at depths approved by the State;

(d) provisions should be made to assure minimum vertical rise;

(e) top of caisson should be covered with watertight floor;

(f) all openings in floor should be curbed and protected from entrance of foreign material;

(g) pump discharge piping should not be placed through caisson walls.

Infiltration Lines

(a) considered only where geological conditions preclude possibility of developing an acceptable drilled well;

(b) area around lines should be under control of water purveyor for distance acceptable to or required by the State.

(c) flow in lines should be by gravity to collecting well;

(d) water should be continuously chlorinated.

2.4.4 Springs(I-30)(II-18)

Springs will be approved only after an extensive sanitary survey. The amount of land required for protection of the spring will be determined by the State.

Factors to be considered in the development of springs include:

(a) Springs should be protected from entry of surface water. Provide diversion ditches where necessary.

(b) A spring to be developed as a ground water source should be protected by a permenent enclosed structure. The walls of the enclosed structure should extend down to bed-rock, or into the soil sufficiently to provide for a proper foundation and to prevent surface water seepage. Make provisions for emptying and cleaning structure.

(c) The over-flow from the spring enclosing structure should be designed to prevent contamination of the spring.

(d) Flooding of the spring by back-flow is prohibited.

(e) Any pumping or water treatment facilities should be enclosed in shelters which are of weather-and-vandal-proof construction.

(f) The spring area should be fenced to prevent unauthorized entry.

(g) All water from springs should be subjected to continuous disinfection as minimum treatment.

(h) The water utility should furnish the State with samples of the raw water for bacteriological examination. The utility should also furnish results of the physical and chemical analysis of the untreated water performed by an approved water testing laboratory in order that it may be determined what treatment is necessary to provide a finished water. See Section IX for continuing Surveillance requirements.

2.4.5 Wells(I-30)(II-4)

2.4.5.1 Minimum protective depths of drilled wells should provide:

(a) watertight construction to such depths as may be required by the State to exclude pollution,

(b) design to seal off formations that are, or may be, contaminated or yield undesirable water,

(c) annular opening of at least 3.81 cm (1.5 inches) outside the protective casing filled with:

  (1) concrete grout, or

  (2) neat cement grout, or

  (3) other approved material.

(d) protection against surface water contamination.

2.4.5.2. Special Protection:

Gravel Wall Wells

(a) gravel should be free of foreign material, properly sized, washed and then disinfected prior to or during placement;

(b) gravel refill pipes, when used, should be incorporated within pump foundation and terminated with screwed or welded caps at least 30.5 cm (12 inches) above pumphouse floor or concrete apron;

(c) gravel refill pipes in grouted annular opening should be surrounded by a minimum of 3.8 cm (1 1/2 inches) of grout;

(d) prevention of leakage of grout into gravel pack or screen should be provided.

Dug or Bored Wells

(a) considered only where geological conditions preclude possibility of developing an acceptable drilled well;

(b) watertight cover should be provided;

(c) minimum protective lining and grouted depth should be acceptable to the State;

(d) openings should be curbed and protected from entrance of foreign material;

(e) water used in construction should be from source approved by the State;

(f) minimum protective casing and grouted depth should be acceptable to the State.

Sand or Gravel Wells

(a) if clay or hardpan is encountered, inner casing and grout should extend through such materials;

(b) outer casing can be removed or withdrawn as grouting proceeds;

(c) outer casing left in place should be withdrawn to at least 1.5 meters (5 feet) above clay, hardpan or similar material.

Limestone Wells (also see Section 2.4.2.2)

(a) where depth of mantle over considerable area is more than 15.2 meters (50 feet), the casing should be firmly seated in uncreviced rock;

(b) where depth of mantle is less than 15.2 meters (50 feet), the State should be consulted for required casing depths;

(c) minimum depth of grout should be 15.2 meters (50 feet);

(d) need for treatment, or use without treatment, should be determined by the State.

Sandstone Wells

(a) minimum depth of protective casing should be 15.2 meters (50 feet);

(b) where depth of mantle is more than 15.2 (50 feet), protective casing should be firmly seated in firm sandstone where sandstone is first rock formation;

(c) where depth of mantle is less than 15.2 meters

(50 feet), the State should be consulted as to required depth of protective casing.

Flowing Artesian Wells

(a) flow should be controlled;

(b) protective casing and grout should be provided;

(c) if erosion of the confining bed appears likely, an inner casing, joined watertight to the protective casing should be provided.

2.4.5.3 General Well Construction Requirements:

Location - See Section 2.4.2.2

Casing and liner pipe of wrought iron or steel

(a) should be prime pipe meeting ASTM or API specifications;

(b) for driven casings, should have minimum weights, and thickness given in the AWWA Standard for Deep Wells, AWWA A100-66, p.34 and 35;

(c) for non-driven casings,

    (1) should be surrounded by a minimum of 10.16 cm (4 inches) of grout;

    (2) should have a minimum thickness of 0.82 cm (0.322 inch);

(d) should have additional thickness and weight if standard thickness is not considered sufficient by the State to assure reasonable life expectance of well;

(e) should be capable of withstanding forces to which they are subjected;

(f) should be equipped with drive shoe when driven;

(g) should have welded or threaded pipe joints.

Pipe other than wrought iron or steel should be adaptable to the stresses to which they will be subjected during installation and to the corrosiveness of the water.

Concrete wall casing should

(a) be at least 15.24 cm (6 inches) thick,

(b) be poured in one operation, if possible,

(c) have construction joint within 3.05 meters (10 feet) of original ground surface.

Pre-cast casing, such as concrete well pipe, vitrified pipe and similar forms should

(a) extend to a depth of at least 3.05 meters (10 feet) below existing ground surface;

(b) be surrounded with at least 15.24 cm (6 inches) of neat cement or concrete grout pumped, vibrated or puddled and placed in one operation.

Packers should be of a material that will not impart taste, odors, toxic substances or bacterial contamination to the water in the well.

Screens should

(a) be constructed of material which will not be damaged by chemical action of ground water or future cleaning operations;

(b) have size of openings to be based on sieve analysis;

(c) be installed so that exposure above pumping level will not occur;

(d) be designed and installed to permit removal or replacement without adversely affecting watertight construction of well.

Yield and drawdown test should

(a) be performed on every well;

(b) have the method clearly indicated in specifications;

(c) have pump capacity at least 1.5 times quantity anticipated;

(d) pump continuously over period indicated, (36 hours or more);

(e) provide data as follows:

    (1) static water level,

    (2) pumping rate,

(3) drawdown during test,

(4) recovery water levels,

(5) depth of pump setting;

(f) provide for samples of water to be collected for quality determinations.

Chemical conditioning should be included in specifications as to method, equipment, chemicals, testing for residual chemicals, disposal of waste, and inhibitors used.

Blasting procedures should be included in specifications as to

(a) location, number and size of charges,

(b) cleaning procedures.

Grouting recommendations:

(a) Concrete Grout

(1) cement and sand 1:1, with not more than 22.7 liters (6 gallons) of water per sack of cement;

(2) where large volumes are required to fill anular opening, gravel not larger than 1.2 cm (1/2 inch) in size may be added.

(b) Neat Cement Grout

(1) cement and water with not more than 22.7 liters (6 gallons) of water per sack of cement;

(2) additives, up to 5 percent by weight, may be used to increase fluidity.

(c) Application

(1) grout should be installed by means of a grout pump from the bottom of annular opening upward in one continuous operation until annular opening is filled.

(2) sufficient annular opening should be provided to permit a minimum of 3.7 cm (1 1/2 inches) of grout around protective casing, including couplings, if used;

(3) Bentonite, Aquajel or similar materials may be added to the annular opening, in the manner indicated for grouting, prior to grouting;

(4) when the annular opening exceeds 10.16 (4 inches) and concrete grout is used, it may be placed by gravity through a grout pipe installed to the bottom of annular opening.

(d) Guides

(1) protective casing should be provided with sufficient guides welded to casing to permit unobstructed flow and uniform thickness of grout.

Plumbness and alignment requirements:

(a) every well should be tested for plumbness and alignment;

(b) test method should be clearly stated in specifications;

(c) kinks and bends are not acceptable;

(d) information should be submitted to the State prior to permanent pump installation.

Geological data should

(a) be determined from samples collected at 1.5 meter (5-foot) intervals and at each pronounced change in formation;

(b) be recorded and submitted to the State;

(c) be supplemented with information on accurate record of drillhole diameters and depths, assembled order of size and length of casings and liners, grouting depths, formations penetrated, water levels and location of any blast charges;

(d) be supplemented with complete pumping test data.

Upper terminal of well, recommendations:

(a) protective casing for all ground water sources must project not less than 15.2 cm (6 inches), and preferably 30.5 cm (12 inches), above pumphouse floor or cover installed;

(b) site not subject to flooding should have floor of pumphouse and cover of every dug well at least 30.5 cm (1 foot) above original ground surface;

(c) site subject to flooding should have cover of every dug well and the floor of the pumphouse at least 0.61 meters (2 feet) above the highest known flood elevation and be surrounded by earth fill as required by the State.

Capping recommendations:

(a) a properly fitted, firmly driven, solid wooden plug is an acceptable method of capping a well until pumping equipment is installed;

(b) a welded metal plate is preferred for capping a well;

(c) well should be protected during construction, by temporary cap.

2.4.5.4 Bacteriological Quality:

(a) every new, modified or reconditioned ground water well source should be disinfected after placement of final pumping equipment;

(b) one or more water samples should be submitted to a laboratory satisfactory to the State for bacteriological analysis, with the results reported to such agency.

2.4.5.5 Chemical Quality:

(a) every new, modified or reconditioned ground water well source should be examined for chemical characteristics by tests of a representative sample in a laboratory satisfactory to the State with the results reported to such agency;

(b) samples should be collected and tested as soon as practical;

(c) determination of pH should be made in the field;

(d) samples for iron analysis should be acidified;

(e) examination should be made for hydrogen sulphide and methane where these gasses are suspected.

2.4.5.6 Water Level Measurement:

(a) provisions should be made for periodic measurement of static and pumping water levels in completed well;

(b) installation should be made in such manner as to prevent entrance of foreign material.

2.4.5.7 Observation Wells:

(a) should be constructed in accordance with the requirements for permanent wells if they are to remain in service after completion of ground water supply;

(b) should be protected at the upper terminal to preclude entrance of foreign material.

2.4.5.8 Well Abandonment:

(a) test wells and ground water sources which are not in use should be sealed by such methods as to restore the controlling geological conditions which existed before they were constructed;

(b) wells to be abandoned should

   (1) be sealed to prevent exchange of water from one geological strata to another,

   (2) be preferably filled with concrete,

   (3) have fill materials which are other than concrete to be free of foreign material and disinfected,

   (4) not be filled with concrete to be dropped through water,

   (5) meet other State requirements.

2.4.5.9 Pitless Units for Public Water Supply Wells

Pitless units should provide for:

(a) access to disinfect the well;

(b) a downward-facing screened vent or breather that will not admit contamination into the well;

(c) facilities to measure the static and pumping level in the well without contamination;

(d) a cover that will prevent contamination at the upper terminal of the well;

(e) a contamination-proof entrance connection for electrical cable;

(f) an inside diameter as great as that of the well casing to facilitate work and repair on the well, pump, or well screen;

(g) a check valve within the well casing, or in compliance with requirements of the reviewing authority.

2.4.5.10 Duplicate Installations Recommended

In supplies derived entirely from ground water sources, duplicate wells and pumping equipment, or equivalent, should be provided. An emergency interconnection with another approved public water supply may be accepted in lieu of a duplicate installation.

RATIONALE FOR SOURCE DEVELOPMENT STANDARDS

2.1.0 General

Either ground or surface water supplies may be developed for public use. Ground water, when available in sufficient quantity, is often preferred. Most ground water is clear, cool, colorless and quite uniform in character. Underground supplies are generally of better bacterial quality and contain much less organic material than surface water, but may be more highly mineralized. The cost of pumping ground water may be greater than the cost of pumping surface water. Adequate natural protection of ground water involves purification of water by infiltration into the soil, by percolation through underlying material, and by storage below the ground water table.

Most surface waters require chemical coagulation, sedimentation, filtration, and disinfection to make them suitable for use as public water supplies. A combination of treatment methods will, if properly carried out, convert a moderately polluted water into a safe drinking water. It is increasingly difficult, because of easier access and greater recreational use of streams, lakes, and watersheds, and urban and industrial development, for unfiltered surface water from protected watersheds to meet the requirements of the Federal Drinking Water Standards.

Most unfiltered surface supplies are unable to produce consistently a suitably clear and colorless water, even though they can sometimes meet bacteriological requirements with suitable catchment areas, prolonged storage in impounding reservoirs, strict control of pollution sources on the catchment and storage areas, and effective disinfection.

Local circumstances and the characteristics of each water supply govern the treatment required and the design and construction of the plant needed to assure that the water delivered to the consumers will fully and consistently meet the Federal Drinking Water Standards for bacteriological, physical, chemical, and radiological qualities.

2.2.0 Quantity and Quality

The delivery capacity of a water works should exceed the anticipated demand for a reasonable time period, say five to ten years into the future. This is usually sufficient time to allow for construction of facilities needed to accomodate community growth. The need for improved water quality through more extensive treatment should be reviewed periodically in the light of the possibility of increased source pollution, better understanding of treatment needs, and new technology.

Preceding page blank

2.2.1 Design Period for Surface Supply Works

As already seen, the quantity of water at the source should adequate to supply the total water demand of a community from that source, as well as a reasonable surplus for anticipated growth, with due regard to the region within which the supply must be developed. In the case of an impounded source, allowances should be made for required water releases, evaporation, seepage, and siltation losses.

The collection works either tap a source of water that is continuously adequate in quantity to satisfy present and reasonable future demands, or they convert an intermittently inadequate source into a continuously adequate supply by storing surplus water for use during periods of insufficiency.

An analysis of the elements making up the total water demand of a community should be made, including but not limited to the following items: (1) location, (2) climate, (3) population growth, (4) type and character of community, (5) fire protection, (6) air conditioning, (7) metering practice, (8) sewerage, (9) cost of water, (10) water quality, (11) pressure on mains. In the case of multi-purpose reservoir projects, the various demands for water should be carefully integrated. For major costly projects which require difficult planning, property acquisition, and financing, such as impoundments, the design period should be, for example, about 50 years.

Where the source of supply is located at some distance from the point of use a long supply line is required, a study should be made of the economic size of the main, taking into consideration cost of construction, expected future growth, and cost of operation based on power costs and other factors. Parts of the supply works which can be expanded without difficulty or excessive costs may be designed for a shorter period such as 20 years. This might include intakes, pumping stations, or certain pipelines.

2.2.2 Design Period for Ground Water Supplies

Major projects such as centralized well field and long transmission lines may not be suited to construction in phases without incurring excessive extra costs, or they may involve difficult planning, property acquisition, or financing. For such projects a design period on the order of 50 years may be appropriate.

For development of scattered wells feeding individually into the distribution system through short pipelines, and for other projects which are readily adoptable to construction in stages, shorter design periods of 10 to 20 years are indicated.

2.2.3 Quantity of Water From Surface Supplies

Development of surface water sources often involves water treatment and the storage of processed water. If there is sufficient storage at the plant or on the distribution system or in the combination thereof to supply peak hourly demands and fire flows, then the maximum draft on the source of supply will be equal to the maximum daily demand and this can be the basis of design of the source of supply for the design period.

2.2.4 Quantity of Water From Well Water Supplies

If sufficient storage of finished water is provided on the distribution system to meet peak hourly demands and to supply fire flows, then the well water supply can be sized to supply only the design maximum daily demand. On the other hand, if there is no storage or very little storage on the distribution system, then the well water source must be designed to supply peak hourly demands and fire flows. In any case, it is good practice to have one standby well equal in capacity to the largest capacity well in the system for emergency use in the event of well failure or outage.

2.2.5 Safe Yield for Flowing Streams

When no channel or off-channel storage is provided, the minimum stream flow of record must exceed the estimated future water demand on the maximum day. The best hydrologic data on minimum stream flows is that recorded on the specific watershed in question. In the absence of such data or with a short period of record, it may be necessary to use estimating methods.

Stream flow and weather records of contributing or adjacent watersheds should be used in estimating the safe yield of the source. Empirical formulas and ratios as contained in published literature vary widely for watersheds of the same size; therefore, they should not be considered satisfactory criteria for judging the adequacy of a source unless supported by hydrologic data obtained from the specific watershed.

A careful study should be made of all factors which affect and determine the safe yield of a proposed surface water source, including such data as geographical location, storm paths, prevailing winds, type and intensity of precipitation, topography and size of basin, orientation of basin, kind of soil, kind of vegetation, condition of ground surface, type and extent of artificial drainage, extent of surface storage in lakes and swamps, condition and slope of stream channel, average slope of basin, character of drainage net, evaporation, infiltration and other losses.

There are many methods of estimating runoff. The accuracy of the various methods depends upon the ability and the experienced judgment of the estimator to find and supply the correlating factors which will produce a realistic synthetic record. Consultation with the U.S. Weather Bureau and the U.S. Geological Survey is recommended.

2.2.6 Safe Yield For Reservoirs And Lakes

When the demand for water is greater than the minimum rate of flow in the stream from which the water is to be taken, an impounding reservoir may be required. The ideal topographic conditions for a reservoir are a narrow gorge in which a dam may be built at minimum expense, and an expanding valley immediately above the gorge which will afford large storage per unit of surface area. This minimizes evaporation loss and the growth of algae and aquatic vegetation.

The necessary reservoir capacity is dependent upon the quantity of water required to supply the community, the amount of water lost by evaporation from the reservoir surface, by seepage through and around the dam, and upon the minimum flow of the stream. The minimum stream flow can be determined accurately only by actual measurement over an extended period of time. Even where such flow records are available there is always the possibility of a more severe drought than any previously recorded. However, all ordinary requirements will be met if provision is made for such droughts that occur not oftener than once in 50 to 100 years.

The amount of storage required to carry the community through any of the recorded past droughts at the estimated rate of consumption may be determined by preparation of a mass diagram based on the best hydrologic data available. Mass curves of run-off should cover a period of several years of minimum rainfall. The engineer should submit calculations to show the probable yield of the proposed source of supply in periods of minimum rainfall as compared to the estimated maximum demands for water expected during the design period.

Approval of the safety features of any planned structures should be obtained from the appropriate agency. Safety in design of a dam in connection with a reservoir requires that the spillway design flood by determined and provision made for adequate spillway capacity.

2.2.7 Safe Yield From Wells

The total quantity of water from all wells (with the largest well out of service) should comply with the requirements of Section 2.2.4.

Every well should be tested for yield and drawdown. The test method to be followed should be clearly outlined in the specifications. The test pump should have a maximum capacity 1.5 times the quantity of water anticipated and minimum capacity 20 percent thereof. The test pump should be able to operate continuously until the water level has stabilized. Test data to be recorded should include water level, drawdown, and pumping rate during the entire test, drawdown in in wells, within 500 feet, and recovery water levels upon conclusions of pumping. Duration of the test should be determined with due consideration given to pumping of sand, clarity of water pumped, and the obtaining of representative samples of water for chemical and bacteriological analysis.

The safe yield of each well shall be estimated taking into account the results of pumping tests, well location and construction, and the minimum static water level and lowest rate of ground water reservoir replenishment during the driest period of record (or projected 100 year drought).

2.2.8 Federal Drinking Water Standards

The rationale for the Federal Drinking Water Standards is given in the appendix to the Standards.

2.2.9 General Treatment Requirements, see EPA "Manual for Evaluating Public Drinking Water Supplies", 1969.

2.2.10 Bacteriological Quality Versus Treatment Requirements

The rationale for the various degrees of treatment required to process waters containing differing concentrations of coliform organisms was derived for the most part from:

a. EPA, "Manual for Evaluating Public Drinking Water Supplies", 1969.

b. Walton, Graham, "Relation of Treatment Methods to Limits for Coliform Organisms in Raw Waters", J.AWWA, p. 1281, October, 1956.

c. U.S.P.H.S., "Effectiveness of Water Treatment Processes as Measured by Coliform Reduction", U.S. Public Health Service Publication No. 898, 1957.

d. Woodward, Richard L., "Relation of Water Quality to Treatment Plant Design", J.AWWA, p. 432, 1964.

e. AWWA Committee Report, "Raw Water Quality Criteria for

Public Supplies", J.AWWA, p. 133, March, 1969.

2.2.11 Chemical and Physical Quality Versus Treatment Requirements

Water should contain no chemical or physical impurities which make it unsafe for human consumption or render it offensive to the senses of sight, taste, or smell. Water which is not appealing to the consumer may prompt him to turn to some other, unsafe source of water. Water should not be excessively corrosive to water mains or house plumbing. Drinking water should not contain impurities that may be hazardous to the health of the consumer. Substances that may have deterious physiological effect, or for which physiological effects are not known, should not be used to treat water in a manner that would allow them to reach the consumer.

Water not conforming to the Federal Drinking Water Standards for chemical and physical quality can, in many cases, be treated to reduce the concentration of the objectionable substances to allowable limits. In other cases, the water quality may need to be improved by dilution with water from a source of better quality. In a few cases, it may be necessary to replace the water of unacceptable quality with water from an approved source.

The specific physical and chemical parameters of water quality which are objectionable either for health reasons or from an esthetic standpoint as delineated in the Federal Drinking Water Standards are listed in Section 2.2.11 under items 2.2.11.1 through 2.2.11.12. Any general methods of treatment which may be useful in removing the objectionable materials are given below under corresponding item numbers. Further details of these treatment methods are given in Section III of this Manual.

2.2.11.1 Inorganic Chemicals

Arsenic

For health reasons, the approval limit for arsenic in water is 0.05 mg/l. Arsenic can be removed from water by ion exchange using beds of activated alumina.

Barium

For health reasons, the approval limit for barium is 1 mg/l. Barium and calcium have similar chemical properties, and barium may be found as an impurity in commercial lime used in water treatment. Any increases in barium content from raw to treated water would indicate a need to check the purity of treatment chemicals.

Cyanide

For health reasons, the approval limit for cyanide is 0.2 mg/l. Cyanides in water often originate from metal plating waste discharges. By treatment at the source, using the alkaline chlorination process, the concentration of cyanides in the treated wastes can be reduced below 0.2 mg/l. The applicability of the alkaline chlorination process to removal of low concentrations of cyanide in water treatment plants is not known.

Cadmium, Chromium, Lead, Mercury, Selenium, and Silver

For health reasons, the approval limits for these heavy metals are:

	mg/l
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Selenium	0.01
Silver	0.05

Concentrations of these metals in water can be reduced by the following process sequences: lime coagulation at pH above 11.0 settling, recarbonation, filtration, and activated carbon adsorption. Cadmium, hexavalent chromium, mercury, and silver are highly adsorbed on activated carbon and this treatment alone may suffice in certain cases. Selenium is adsorbed on activated carbon to a lesser extent. Cadmium, trivalent chromium, lead, and silver concentrations are significantly reduced by lime coagulation at pH above 11 and recarbonation. Cadmium, chromium, lead, and mercury may also be removed by ion exchange.

Nitrate

For health reasons, the approval limit for nitrate is 10 mg/l. Nitrates may be removed from water by ion exchange, but a more common remedy is to seek another source of water which is low in nitrates.

Fluoride

For health reasons, there are limits for fluorides in water. Fluorides may be removed from water by ion exchange or, in some cases by massive alum coagulation, but a more common remedy is to seek another source of water which is lower in fluorides.

2.2.11.2 Organic Chemicals

Carbon-Chloroform Extract (CCE-m)

For health reasons the concentration of CCE-m in drinking water should not exceed 0.7 mg/l. These organics are adsorbable by activated carbon treatment.

2.2.11.3 Pestcides

The concentrations of pesticides in water are restricted for health reasons. If the concentration of any pesticide exceeds the approval limits, the utility should confer with the State to determine if the pollution can be cut off at the source, or if the particular pesticide in question can be adsorbed on activated carbon - many of these agents are adsorbed on activated carbon while others may not be so adsorbed.

2.2.11.4 Turbidity

For health reasons, turbidity in drinking water should not exceed one Turbidity Unit (TU), and preferably should be less than 0.2 TU. High turbidities interfere with disinfection of the water, especially with virus inactivation. Turbidity can readily be controlled by proper coagulation and filtration.

2.2.11.5 Odor and Color

Water having a Threshold Odor number greater than 3 or a color greater than 15 color units is objectionable esthetically to a considerable number of people, and treatment by disinfection, coagulation, filtration activated carbon adsorption, or combinations thereof is indicated to reduce concentrations of these substances to acceptable levels.

2.2.11.6 Foaming Agents

For esthetic reasons the maximum allowable limit of these substances measured as methylene-blue active substances (MBAS) is 0.5 mg/l. Activated carbon adsorption treatment can be used to reduce concentrations below the limit.

2.2.11.7 Iron and Manganese

Iron concentrations in excess of 0.3 mg/l and manganese content greater than 0.05 mg/l in water stain laundry and plumbing fixtures and impair the taste of coffee, tea, and other beverages. These esthetically objectionable elements may be removed from water through oxidation by chlorine or potassium permanganate, coagulation, filtration, ion exchange, or combinations of these treatment processes.

2.2.11.8 Copper, Zinc, and Hydrogen Sulfide

The presence in water of copper in excess of 1 mg/l, zinc in excess of 5 mg/l, or hydrogen sulfide in excess of 0.2 mg/l is esthetically objectionable. These substances can be removed by high pH lime coagulation, recarbonation, and filtration.

2.2.11.9 Chlorides and Sulfates

Chlorides or sulfates at levels greater than 250 mg/l in water are esthetically unacceptable. They may be removed by demineralization of the water, but usually this is not practical. One remedy is to dilute water from a source high in chloride or sulfate with water from a better source. Another is to seek a better source of supply.

2.2.11.10 Sodium

No limit designated, but the water utility should periodically notify local physicians of the sodium content of the public water supply so that they may advise their patients of suitable dietary restrictions.

2.2.11.11 Radioactivity

Approval limits (Health) for finished drinking water cannot be based on an assumed harmless level of radiation dose. Rather, controls for both individual and population exposures should be based on the prudent assumption that there is no threshold dose for damage from ionizing radiation and that any health effects will be proportional to the dose delivered by the ingested activity.

Since the absence of health effects cannot be assumed, the radiological quality of water must meet two criteria. Not only must the risk to individuals using the water supply be small but also the total health impact on the population using the water supply system must be limited, a criterion best met by considering the sum of all the individual doses received by those persons using the supply. This aggregate dose, in units of man-rems or organ-rems is computed by multiplying the number of persons using the supply by the average annual total body or organ dose an individual receives by ingesting the water. A numerical example of an aggregate dose calculation is given in item (c).

(a) Radium-226, other alpha particle emitters, and Radium-228.
Approval Limit (Health)
Aggregate dose limit to the population served by any water supply system shall not exceed - 3000 organ-rem/yr. In no case, however, shall the average annual concentration be greater than:
Radium-226 and/or Radium-228 - 5 pCi/l
Gross alpha particle activity* (including Radium-226) - 15 pCi/l.

Substances that emit ionizing radiation in the form of alpha particles are harmful to the tissue of the organ in which they lodge because of the high density transfer of the energy from alpha particles to surrounding tissue. Of all the substances frequently found in water, radium-226 and radium-228 are particularly hazardous because they produce a chain of alpha emitting decay products which are retained in the bone.

The organ dose for bone seeking radionuclides is computed on the basis of the dose to bone surfaces. The limiting concentrations of radium-226 and radium-228 listed above should result in bone surface doses no larger than 60 millirem per year. Because the daily intake of radium-226 from food usually equals or exceeds 1 pCi, the amount of radium in the skeleton is relatively insensitive to the quantity of radium-226 in drinking water at concentrations less than 0.5 pCi/l. Consequently, radium concentrations below 0.5 pCi/l need not be considered in computing the aggregate dose. Table A lists allowable concentrations of radium-226 and/or radium-228 as a function of the population served by the public water supply system.

---

*Corrected for the contribution, if any, due to radon and uranium.

TABLE A

Population Served (In Thousands)	Radium-226 and/or Radium-228 pCi
50 or less	5
100	2.5
200	1.3
300	0.8
400	0.6
500 or over	0.5

In the case of radium contamination, dose reductions may be realized by water treatment such as softening, dilution with less radioactive water (usually surface waters) or by switching entirely to a raw water supply containing a lower concentration of radioactivity. In all cases such alternatives should consider both the effect of such changes on the overall quality of the finished drinking water and the most economical means of realizing the required dose reduction.

(b) Beta particle and photon activity from artificial radionuclides.
Approval Limit (Health)
Aggregate dose limit for the population served by any water supply system shall not exceed - 15,000 man-rem/yr.
In no case, however, shall concentration produce in any individual a yearly dose to the total body or any internal organ greater than - 0.015 rem/yr.

The drinking water limit is expected to limit any individual's dose to about 1% of the allowable maximum industrial exposure. Federal radiation protection guides for radiation workers limit whole body exposures to 5 rem per year, or 333 times the drinking water approval limit. For a heterogeneous population group, a factor of three has been suggested as sufficient allowance between the average and maximum dose received by members of the group.

Compliance with these approval limits may be based either on dose calculations for radionuclides quantitatively identified as being in the finished water or gross beta counting and specific radionuclide measurements as follows:

Except for the isotopes listed in Table B, limiting concentrations of man-made radionuclides causing 0.015 rem total body or organ dose can be calculated using the 168 hour data listed in "Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air and in Water for Occupational Exposure", MBS Handbook 69. Alternatively, compliance with the individual dose limit for total body or organ dose may be certified by a gross beta particle emission of less the 100 dpm per liter** and a concentration less than those listed in Table B for specific isotopes. If stron-90 and tritium are both present, the sum of doses to the bone marrow must be considered. If the gross beta activity exceeds 100 dpm/l, a radio-chemical analysis of the sample should be performed to identify the radioactive consistuents and the appropriate total body and organ doses calculated.

TABLE B

Limiting Annual Average Concentrations Assumed to Produce a Total Body or Organ Dose of .015 rem per year

Radionuclide	pCi/liter
Tritium	8×10^4
Strontium-90	8
Iodine-131*	

Compliance and monitoring requirements for radioactivity depend on the size of the public water supply system and its location in relation to nuclear facilities and known contaminating events that may be a source of planned or unplanned releases of radioactivity. The water utility may determine that because of the known absence of facilities having a potential for radionuclide releases, routine monitoring for the radionuclides listed in Table B is either unnecessary or needed only on an interim basis.

*Based on a one liter daily intake by a 1 year old child.

**An evaporated sample corrected for the contribution, if any, by potassium-40 or other naturally occurring radionuclides.

All water supplies regardless of size must meet the annual 0.015 rem dose limit for individuals for beta activity. Within such limits, only water supply systems serving more than 100,000 people are potentially capable of exceeding the aggregate annual dose limit of 1500 man-rems. While most water supplies of this size can be monitored for the aggregate dose limit, its determination on a routine basis would be both expensive and difficult for a few of the nation's largest supply systems. For this reason, compliance with the aggregate dose limit may be assumed, regardless of the size of the water supply, if the gross beta count is less than 100 dpm/l, and the concentration of specific radionuclides is less than that shown in Table C. It should be noted that the values listed in Table C are not given fraction of Table B limits corresponding to be a de minimus dose. Rather the limits in Table C are based on their practicality for routine monitoring.

TABLE C

Limiting Annual Average Concentrations for Assessing Aggregate Dose

Radionuclides	pCi/liter
Tritium	2×10^3
Sr-89	1×10^1
Sr-90	1
I-131	0.4
Cs-134	2
Cs-137	2

The concentration of Cs^{134} required to produce 0.015 rem year dose rate is 300 pCi/l, and the critical organ is the total body.

The concentration of tritium required to produce a 0.015 rem yearly dose rate is 80,000 pCi/l (from Table B) and again the critical organ is the total body.

(c) A procedure for calculating the aggregate dose from two or more two or more radionuclides.

Needed input parameters:

P - the population served by the supply*
C_1 - the concentration in pCi/l needed to produce a total body or organ dose rate of 0.015 rem/year from a 2 liter daily intake of isotope 1.
C_2, C_3 as above for isotopes 2, 3, etc.

If X_1 is the annual average concentration of isotope 1 in a given water supply, the yearly dose rate to an average consumer from this isotope is:

> $0.015\ X_1/C_1$ rem/year and the annual population dose rate is P times this average dose rate, i.e., $0.015\ P\ X_1/C_1$ person rem per year.

For all artificial radionuclides in the supply, the population dose rate is:

$$0.015\ P \left\{ \frac{x_1}{C_1} + \frac{x_2}{C_2} + \frac{x_3}{C_3} \right\} = \text{person rem/yr.}$$

Numerical example:

A supply serving 1,5000,000 persons contains ^{134}Cs at an average concentration of 10 pCi/liter and tritum at 2,000 pCi/l.

$$\text{Annual population dose rate} = 0.015 \times 1{,}500{,}000 \ \overbrace{\frac{10}{300} + \frac{2{,}000}{80{,}000}} =$$

1260 person rem per year

i.e., less than 1500 person rem per year.

2.2.11.17 Asbestos

Recent developments have resulted in an increasing awareness of the potential hazards of asbestos in the environment. Among these developments have been the banning of a number of asbestos containing products by the Food and Drug Administration, and the promulgation of emission standards for asbestos in air by the Environmental Protection Agency.

---

*N.B. if P is less than 100,000 persons only individual limits apply.

The thrust of these developments has been to focus attention on the occurrence of asbestos fibers in drinking water, and particularly the contribution of fibers from asbestos-cement pipe. Although there appears to be little information showing adverse health effects from waterborne asbestos, one group, the Center for Science in the Public Interest, has suggested the banning of asbestos-cement pipe for potable water uses.

The data available on the asbestos content of water supplies is extremely limited, and the subject is complicated by the lack of a standard method for detection and analytical reporting of asbestos or fiber contents. Before an accurate appraisal of the asbestos in water situation can be made, a standard method will have to be developed and more data will have to be accumulated and evaluated. Toward this end, EPA plans to: (1) convene a study group to recommend a standard method for the analysis of asbestos fibers in water; and (2) initiate a research project to determine the degree of hazard from asbestos in drinking water.

Present indications are that, while asbestos fibers and fibrils are contributed to drinking water during passage through asbestos-cement pipe, particularly in situations where the water is aggressive and/or where the pipe has been cut or tapped in the field, the amounts are not significantly greater than the background levels in many instances. Much higher fiber concentrations are found in ground waters which emanate from serpentine rock formations.

Eventually, standards for the asbestos content of drinking water may have to be developed, depending on research findings regarding the health effects of asbestos in water. Such standards will be set in conjunction with airborne asbestos limits, since both air and water contribute to the overall exposure. On the basis of the 1976 industrial exposure limits for airborne asbestos, 2 fibers per cubic centimeter, an individual with a normal breathing pattern will be exposed to 46,000 fibers in 24 hours (0.8 liters per breath, 20 breaths per minute), if the air is at the upper limit permitted. For comparison, normal fiber contents of drinking water according to optical microscopy measurements, range from less than 1,000 to 26,000 fibers per liter. Samples of ground water from serpentine rock formations have been found to contain up to 250,000 fibers per liter. Even using the highest concentration reported, the exposure from water would still be only a fraction of the total permissible based on the industrial exposure limits for airborne asbestos. It has been noted that any asbestos contributed to the water by asbestos-cement pipe is additive, regardless of the natural level, but in all data available at this time, the amount contributed appears to be relatively minor.

Until such time as the hazards from asbestos in water can be accurately assessed, and until the role of asbestos-cement pipe in this situation can be determined, definite recommendations either cannot be made for or against the use of this pipe for distribution mains. However, it is prudent to recommend the implementation of available means for limiting the amount of asbestos entering drinking water when the pipe is so used. For example, limiting the extent of field cutting and tapping of the pipe will limit the contact of raw edges with the water. Consideration should also be given to lined asbestos-cement pipe where it is available.

It is hoped that an appropriate research project will provide sufficient information to make the necessary assessment of the asbestos issue as a prelude to appropriate standards and control procedures.

2.3.0 Surface Water

2.3.1 River Intakes

The design and construction of river intakes frequently involves difficult problems because of unsatisfactory foundations, shifting shorelines, ice, silt and variable water surface. Location of such intakes should take into account channel changes so that a continuous supply of water is insured; they should preferably be located on the outside or concave bank in a well established river bed where the water is usually the swiftest and deepest. A dependable river intake can usually be constructed along a river's edge against a rocky bank, providing sufficient water depth is available at minimum stream flow. A low water dam may be desirable when sufficient depth is not available. Where it is necessary to construct an approach channel to the inlet structure, it should be as short as practicable. The operating floor should be above the highest possible flood level and accessible at all times.

The intake should be designed to minimize silting or obstruction by deposits of bed load. A sand trap may be necessary to protect pumps. Intakes should be located upstream of sewer outlets, bathing beaches, or other sources of contamination in the immediate vicinity of water supplies taken from rivers.

2.3.2 Impoundments

2.3.2.1 Site Selection

In the absence of natural ponds and lakes, intensive utilization of water sources requires the construction of impounding reservoirs. The selection of a suitable site for a reservoir depends upon a number of interrelated factors that establish the adequacy, economy, safety, and palatability of the supply. The surface topography should be such as to create a high ratio of water storage to dam volume; a broad and branching valley for the reservoir should impinge upon a narrow gorge for the dam. The topography should also present a favorable site for an adequate spillway to pass the flood flow and a suitable route for an aqueduct or pipeline.

The subsurface geology should be such as to provide useful materials for the construction of the dam and appurtenant structures, safe foundations for the dam and spillway, and tightness against seepage of the impounded waters beneath the dam and through its abutments.

The reservoir area to be flooded, should be sparsely inhabited, not heavily wooded, and not traversed by important roads or by railroads. It should contain little marshland. The area should constitute a reservoir of such shape as not to favor short-circuiting of the incoming waters to the intake, and of such depth, especially around its margins, as not to create large shallow areas. Purification of water by storage is an important asset of impounding reservoirs. Narrow reservoirs with their major axis in the direction of prevailing winds are especially subject to short-circulating. Shallow areas often support a heavy growth of aquatic vegetation, where they are submerged, and of land plants, when they are uncovered by the lowering of the water surface. Decaying vegetation imparts odors and tastes to the water, supports algal growths, and liberates color.

The reservoir should interfere as little as possible with existing water rights; the intake should be as close as possible to the community it is to serve; and the development should preferably be at such elevation as to supply its waters by gravity.

2.3.2.2 Sanitary Survey

A survey and study should be made of the factors both natural and man-made, which may affect the quality of a water supply source. The designing engineer must prove, to the satisfaction of the State, that the surface water source under consideration is amendable to the treatment proposed, with respect to complete conformance to the Federal Drinking Water Standards for bacterial, chemical, physical, and radiological quality of water delivered to consumers.

The character of the soil and rock of the drainage basin influences the kind and amount of mineral matter in the water. These are important considerations in the selection of a water source. A geologist, or an aquatic biologist with knowledge of soils and their effect on the growth of taste-and-odor-producing organisms, may need to be consulted on the selection of a reservoir site. Consideration should be given to seepage of poor quality ground water into proposed impoundment areas.

Precipitation, temperature, sunshine, evaporation, and air movements all influence the quality of surface waters, and therefore, should be evaluated. For example, if heavy rains and floods with their resulting turbidities, should all occur during winter months, while in the summer rains are light and the water becomes clear, algae growth will be much greater than if the conditions were reversed. The vertical circulation of water in a lake or reservoir, also is related closely to climatic conditions, and should be considered.

The extent of soil erosion on the drainage basin should be evaluated, as this will determine the quantity of sand and silt reaching the water works intake or reservoir site, and, to a great extent, the amount of this material to be handled by subsequent water treatment processes. Soil erosion affects also the biological productivity of a stream, lake, or reservoir, which in turn influences the quality of the water. Under severe soil erosion conditions, subsequent siltation may limit seriously the effective life of the reservoir as a source of water supply.

The uses of the land located on the drainage basin should be known before selecting a surface water source, because they may affect the water quality. For example, lakes and reservoirs which are fed by water draining from highly cultivated farming areas often produce extensive algae growths, the products of which are difficult to remove. Fertilization for field crops results in the addition of nitrates and phosphates which may stimulate aquatic growths. Immense algae blooms have been found in small lakes and reservoirs under these conditions, and have created difficult water treatment problems. Pesticide use should be investigated and evaluated.

The physical and biological processes associated with surface waters are important factors in natural purification. These processes should be evaluated, and subsequent treatment processes should be designed accordingly; but seldom should these natural processes be relied upon to assure a bacteriologically safe water. Small ponds in a drainage net are frequently breeding places for troublesome organisms; therefore, a self-draining watershed area is desirable. A study should be made of the biological life of lakes and reservoirs, to obtain the most satisfactory location for the water intake. The biological life at different locations, water elevations, and seasons should be evaluated.

Peat bogs, mucky areas, swamps and marshes on a drainage basin contribute a great amount of organic material to the waters draining from them which may cause foul odors, undesirable tastes, acid conditions and high color. These areas should be avoided, or reduced to a minimum by artificial drainage.

Narrow, deep bodies of water, having a minimum of shore line, are better sources of water generally, than shallow ones having extensive flats which are exposed by periodic low water levels. These features also determine the period of detention, and the probable flow time from sources of pollution through lake or reservoir to intake, and so should be evaluated.

The extent of industrial development on the drainage area should be evaluated, as wastes therefrom often contain products which are difficult or impossible to remove by water treatment processes. In addition, dams, dikes, diversion channels, and other works maintained for industrial purposes on the basin, should be studied, as they may indirectly influence the quality of the water. The operation of land, air, and water conveyances on or over surface water sources should be investigated, as these waters may readily become contaminated by excreta discharged therefrom. Commercial fishing, ice-cutting, lumbering, warehousing, landfills, and dumps should be investigated.

The quantity of raw and treated sewage discharged into a surface water source should be determined, and its public health significance carefully evaluated. This investigation should include the possibility of combined sewer spills into the surface water source. The effects of growth-producing materials in sewage upon the algae population, and their relation to water quality, should be considered. Pollution control programs should be evaluated.

The extent and character of present and future recreational activities on the drainage basin should be known, as they may affect the sanitary quality of the water. The health laws, rules, and regulations of local health departments concerned should be consulted on this matter.

The damage to surface water sources which may be caused by the actions of erosion and sedimentation warrant an evaluation of existing watershed management practices, such as terracing, strip and contour farming, maintenance of soil cover, planting of winter cover crops, control grazing, fire control, lumbering operations, road building, etc.

The lower layers of water in a lake or reservoir which receives organic matter may undergo stagnation due to thermal stratification. Stagnation effects such as rising color, increasing organic matter, oxygen depletion, pH depression, and unpleasant odors, should be evaluated in connection with the location of a water works intake.

The death and decay of vegetation in lakes and reservoirs, and on the drainage basin, injure the quality of the water by increasing the organic matter and producing food material for micro-organisms. The various classes of vegetation existing on the drainage basin should be known, and their effect on the quality of water and the methods for control should be evaluated.

Turbidity, color, odor, and taste in a water supply are important considerations from a public health standpoint, because the average consumer erroneously associates these qualities with the safety of water. Therefore, surface water sources which have physical properties which impose intolerable burdens on normal water treatment should be avoided whenever possible. There are also certain surface water sources which, because of the nature and excessive amount of the suspended material carried, will require presedimentation, and possibly other preliminary treatment before they can be considered acceptable for normal treatment.

Surface waters which can be rendered free of harmful concentrations of chemical substances as set forth in the Federal Drinking Water Standards by reasonable treatment may be approved as satisfactory sources of public water supply.

2.3.2.3 Preparation of Site

Vegetation should be removed from the area to be flooded by a proposed reservoir to prevent its decay and subsequent impairment of the physical character of the stored water. Even then, the organic content and color of the stored water will increase for a period of three to five years until stable conditions develop.

The ideal reservoir site is one where the slopes are relatively steep thus insuring deep water over most portions of the reservoir and minimizing the growth of algae, which are most prolific in shallow portions of reservoirs. The periodic exposure of shall areas during periods of low water also leads to the growth of semi-aquatic vegetation, which will die and decay when the reservoir fills again. Shallow areas, therefore, should be filled, or isolated by dikes when economically feasible.

2.3.2.4 Protection of Source

The approval of minimum treatment facilities for surface water obtained from lakes and ponds may require some regulation by the water utility to limit the concentration of bacteria to that which the plant can safely remove. Strict control should be exercised over possible sources of fecal pollution.

The marginal shoreline land should be controlled by purchase and/or a water utility ordinance. The ordinance should describe the water district boundaries and set forth for enforcement any rules and regulations of local, state, or regional health authorities for the protection of the water supply. The ordinance should include:

a. Provisions for regulating the public health aspects of water supply, waste and sewage disposal, malaria control, and recreational activities.

b. Provisions for regulating the building of any structures within the controlled area.

c. Provisions for clearing of timber, brush and debris.

d. Provisions for regulating aquatic activities involving body contact with the water.

e. Provisions for controlling mosquito propagation in the reservoir by effective methods not detrimental to fish and wildlife, recreation, and public health.

Shore installations, marinas, boats and all habitations on the watershed shall provide satisfactory sewage disposal facilities. Septic tanks and soil absorption fields, tile or concrete sanitary sewers, sewer manholes or other approved toilet facilities shall not be located in the area within 23 meters (75 feet) horizontally from the 100 year flood elevation.

Catchment areas occassionally contain swamps which are of significance because swamp drainage imparts color to the water. Furthermore, shallow pools of water in the swamp area frequently support a prolific growth of microorganisms which are washed into the outlet stream. Many swamps may be drained in an economical manner by ditching and cleaning channels of small streams. Such improvements are very desirable because the reduction in the color and content of microorganisms thereby secured is permanent with proper supervision and maintenance.

Contamination of water supplies from pasturage of animals is undesirable. The wash from animal excreta introduces bacterial organisms into a supply which results in unfavorable bacteriological analyses of the water. Drainage from manure may increase nitrogen and phosphorus content and encourage growth of algae detrimental to the water.

The population density of the watershed should be determined yearly to forecast the need for more extensive treatment. This should include assessment of possible pollution from industrial, agricultural, or recreational sources.

2.3.2.5 Recreational Use Effects

Bathing, water skiing, boating, fishing, or other recreational activities in or on any water used as a source of water supply should be conducted in a manner that the water quality will not be adversely affected as a source of water supply by these activities.

Where minimum treatment facilities are provided it may be advisable to establish a restricted zone of 60 meters (200 ft.) radius from the raw water intake works to prohibit all recreational activities and trespassing in this area. The restricted zone should be designated with markers or buoys. Regulations governing this zone should be included in ordinances or rules promulgated by the regulatory agency. Provisions should be made for strict enforcement of such ordinances or regulations.

2.3.2.6 Mixing or Aeration

Commercial equipment is now available for installation in reservoirs for purposes of aeration, mixing, turnover, destratification, and prevention of ice cover. In the absence of adequate naturally occurring water circulation in reservoirs stratifications of temperature and dissolved oxygen can take place. The development of anaerobic conditions on the bottom of the reservoir due to oxygen stratification often results in the dissolving of iron and manganese from the bottom muds. Complete ice cover can be objectionable due to loss of surface reaeration. For these and other reasons, consideration should be given to the installation of an aeration-turnover system in impounding reservoir. The capital and operating costs are quite low.

2.3.2.7 Selection of Depth of Withdrawal

Attention should be given to the construction of intakes so that they may be operated as necessary to secure water from that depth which produces the best water from that depth. Intakes, therefore, should be fitted with at least three gates whereby water can be secured near the surface, about mid-depth, and several feet above the bottom of the reservoir. In this way surface water may be used when decomposition of organic matter is leading to the production of odors and to the removal of dissolved oxygen which in turn leads to the solution of iron and manganese from the flooded soil or rock. On the other hand, the intermediate or lower gate may be used when microorganisms are prevalent near the surface (to be expected in late spring and early summer), or the lower gates may be used in the summer to secure waters cooler than at the surface.

2.3.2.8 Evaporation, Seepage, and Siltation

As mentioned previously, water losses from reservoirs due to evaporation, seepage, and siltation must be taken into account in arriving at total storage requirements. In addition, any precautions or provisions should be taken in design, construction, and operation of the reservoir which will minimize these losses. The engineer should describe the provisions which have been made in this regard.

2.3.3 Structures

2.3.3.1 Dams and Spillways

The water utility should obtain approval of safety features for stability and spillway design from appropriate reviewing authorities. In addition, the utility should obtain any permits required for controlling stream flow or construction in navigable stream or interstate waters.

2.3.3.2 Intakes

The purpose of the plant intake is to withdraw continuously adequate quantities of the best available grade of raw water. When selecting the intake location, the lake bottom character, currents, and potential sources of pollution must be considered. To provide for the variability of environmental influences, the intake structure should be designed and built to permit raw water withdrawal at various levels, or locations, or both. The intake capacity, including pumping facilities, should provide sufficient raw water for the treatment plant at all times. The quantity of finished water in storage provides a buffer and is a factor in determining the necessary intake capacity. This intake capacity generally equals the average rate of demand on the maximum day. Dual facilities should be provided for mechanical equipment. Pump priming must not create a cross connection between the finished and raw water supplies.

Intake facilities should also be constructed to ensure continuous raw water flow despite floods, icing, plugging with debris or sand, high winds, power failure, damage by boats, or any other occurrences; be inaccessible to trespass; contain adequate toilet facilities; located and installed to prevent chance contamination of the raw water supply; and contain an immediate warning system for the treatment plant operator in case of failure of automatic or semi-automatic pumping operations. Since many intakes will be constructed on permeable material, the design of the structure shall take effect of underflow and hydrostatic uplift pressure.

2.4.0 Ground Water

2.4.2 Location and Protection

Adequate natural protection of ground water involves purification of water by infiltration into the soil, by percolation through underlying material, and by storage below the ground water table.

Ground water, when available in sufficient quantity, is often a preferred source of water supply. Such water can be expected to be clear, cool, colorless, and quite uniform in character. Underground supplies are generally of better bacterial quality and contain much less organic material than surface water but may be more highly mineralized.

When water seeps downward through overlying material to the water table, particles held in suspension, including microorganisms, may be removed. The extent of removal depends on the depth and character of the overlying material. The bacterial quality of the water also generally improves during storage in the aquifer because time and storage conditions are usually unfavorable for bacterial multiplication or survival. Of course, the clarity of ground water does not guarantee safe drinking water, and only adequate disinfection can guarantee the absence of pathogenic organisms.

All ground water withdrawal points should be located a safe distance from sources of pollution. Sources of pollution include septic tanks and other individual or semipublic sewage disposal facilities, sewers, and sewage treatment plants, industrial waste discharges, land drainage, farm animals, fertilizers, and pesticides. Where water resources are severely limited, ground water aquifers subject to contamination may be used for water supply if adequate treatment is provided.

After the decision has been made to develop a water supply in an area, the direction of water movement during proposed withdrawal conditions and the safe distance from potential pollution sources should determine the withdrawal point. A safe distance is the distance that ensures no contamination will be drawn or will flow to the withdrawal point when conditions of pollution sources, withdrawal, and water table levels are the most adverse.

Because many factors affect the determination of safe distances between ground water supplies and sources of pollution, it is impractical to set fixed distances. Where insufficient information is available to determine the safe distance, the distance should be the maximum that economics, land ownership, geology, and topography will permit. If possible, a well site would be located at an elevation higher than that of any potential source of contamination. It should be noted that the direction of ground water flow does not always follow the slope of the land surface.

2.4.3 Infiltration Galleries

An infiltration gallery is essentially a horizontal well that collects water along its entire length. Such galleries are usually laid in the alluvium near a body of surface water but are sometimes constructed beneath the surface water. Infiltration galleries are subject to the same sanitary hazards as shallow wells but have greater exposure to pollution because of their horizontal polition. There are several precautions to be taken against contamination. To ensure adequate removal of suspended matter and bacteria, each infiltration gallery should be constructed and located to provide the collected water the maximum filtration through soil and sand. With the exception of service facilities, the surface area above and within a minimum of 30 meters (100 feet) or a safe distance of each fallery should be void of buildings and dwellings and should be protected by a fence to prevent trespass of livestock and unauthorized persons. Disinfection and other unit treatment processes should be accomplished according to provisions contained in other sections of this Manual.

2.4.4 Springs

Water appears at the ground surface from springs of two types, gravity and artesian. Gravity springs occur when the aquifer in which water is percolating laterally comes to the surface because of a sharp drop in surface elevation below the normal ground water table or when obstructions to flow result in an overflow at the surface. Artesian springs are formed when faults in impermeable strate permit artesian water to escape from confinement. Artesian springs discharge from artesian aquifers at pressure higher than the discharge elevation and are usually freer from environmental hazards than are gravity springs. The nature of the strata underlying porous strata should be known, and the possibility should be considered that water may enter the aquifer through a sinkhole or other large openings. The slope of the water table should be ascertained. The quality of water derived from springs should be protected from surface contamination even if processed as a surface water. There are several requirements to be met. Springs should be housed in permanent buildings or structures with watertight walls. For surface springs, the walls should extend into the aquifer. Direct surface drainage should be diverted away from the spring. The entire area within 30 meters (100 ft) of the spring should be fenced to prevent trespass of livestock and unauthorized persons. Any portion of surface drainage diversion ditches lying above the spring should be within the fenced area. Disinfection and other unit treatment processes should be accomplished in accordance with provisions contained in other sections of this Manual.

2.4.5 Wells

2.4.5.1 Minimum Protective Depths

All wells must be properly sealed against surface water contamination. Ground water can be contaminated by surface water entering through the top of the well or by surface water, or water from contaminated aquifers, through which the well passes, that flow down the outside of the well casing to the intake point.

The top of the well must be so constructed that no foreign matter or surface water can enter the well. The well site should be properly drained and adequately protected against flooding. Surface drainage should be diverted away from the well.

When shallow ground water is developed, pathogenic organisms penetrate the water table. Fluctuations of the water table caused by periods of heavy precipitation may at times bring the water table into contact with contaminated zones near the surface. Wells that extend only a short distance into shallow water tables are more likely to be contaminated than wells that penetrate more deeply. The construction of wells with watertight casings surrounded by cement grout protects against surface contamination being drawn to or reaching the casing wall. The depth of grout necessary depends on the individual characteristics of the area involved. When a sanitary survey is made of an existing or proposed well site, nearby sewage disposal facilities, caves, sink holes, abandoned borings used for surface drainage or sewage disposal, and improperly sealed wells should be located, mapped, and evaluated as to possible hazard. Investigation should be made for fissures or faults in the stratum overlying the aquifer.

For drilled wells, the space between casing and well hole should be filled with cement grout to a sufficient depth below grade to prevent surface pollution. Aquifers containing water of undesirable quality should be sealed off from the well casing. The casing must extend 15.2 cm (6 inches) or more above the surface of the well house floor or collar. Casings should not be used as suction pipes.

2.4.5.2 Special Protection

The top level of the gravel packing should be at least 15.2 meters (50 feet) below ground surface. The remaining space above the gravel level should be filled with impervious puddled clay or cement grout. Gravel fill pipes must be securely capped and sealed.

A watertight seal or cover must be provided at the top of the casing.

The connection between the top of the well casing and the power unit must be watertight. The openings for pump suction lines, water level measurement lines, power cables, and lubrication lines must be tightly sealed. Where pump suction lines are outside well casings, the suction lines should be positively protected from environmental hazards.

2.4.5.3 General Construction Requirements for Wells

The specifications for sanitary protection in this Manual are particularly applicable to wells producing water that is not treated or that receives disinfection only. Also see American Water Works Association Specifications A100.

Recharge formations above the tapped aquifer should provide sufficient filtration to prevent contamination from sources of pollution.

Pump houses should be adequately drained and protected against flooding.

The horizontal distance from a well to a source of contamination should be as great as practical.

Well casings should extend into and be sealed to the impermeable stratum immediately above the aquifer.

Vents necessary to maintain atmospheric pressure in the casing should be screened (#24 mesh), with the return bend facing downward, and terminate at least 45.7 cm (18 inches) above the floor level or the maximum flood level, whichever is higher.

2.4.5.4 Bacteriological Quality

Bacteriological sampling and testing after completion of the well, installation of the pumps and discharge piping is necessary in order to be sure that any contamination entering the well system has been removed or rendered harmless by the disinfection procedure.

2.4.5.5 Chemical Quality

Sampling and testing of water from the completed well for chemical and physical quality is necessary to be sure that all contamination by these substances which may have occurred have been flushed or removed from the well and that the water is of suitable chemical and physical quality for human consumption. Poor chemical or physical quality may indicate the need for water treatment, dilution with water of better quality, or abandonment of the source. It is necessary to make pH measurements in the field, otherwise CO_2 or other gases may escape and change the true pH reading. Iron samples must be acidified to prevent oxidation and precipitation of iron by aeration in transit, which gives a false low reading. Tests for H_2S and methane must be made in the field since these gases may escape in sample transit to the laboratory.

2.4.5.6 Water Level Measurement

This information is needed for several reasons. The difference between static and pumping levels or the drawdown, makes it possible to determine the specific capacity of the well and to judge whether the well pump capacity is proper.

Annual variations in static water level provides a means of estimating recharge characteristics and changes in well capacity.

2.4.5.7 Observation Wells

Water level measurements in properly located observation wells used in conjunction with water level measurements in the pumping well can yield valuable data on aquifer yield and ground waterflow.

2.4.5.8 Well Abandonment

Proper reading of abandoned wells is necessary to prevent possible pollution of the ground water aquifer. Sealing protects the quality of water in existing and future wells.

2.4.5.9 Pits

Well pits should be used only where there is adequate protection to prevent flooding, and upon special approval of the State.

2.4.5.10 Duplicate Installations

In order to provide an adequate supply of water with a well out of service for maintenance or repair, it is essential to have a spare or standby well equal in capacity to the largest well in the supply system.

SECTION III. TREATMENT

This section describes detailed considerations involved in the design of numerous water treatment processes, and it presents results which can be expected from proper utilization of such processes. Through appropriate selection and sequencing of individual processes to suit the nature and quality of the raw water supply, it is possible under most conditions to produce a finished water for consumers which will comply fully with the Federal Drinking Water Standards for biological, chemical, physical, and radiological quality. Process control is discussed in Section 9.7.0.

SUMMARY OF TREATMENT STANDARDS

3.1.0 Clarification$^{(III-20)}$

Plants including provisions for clarification should:

a. provide duplicate units for pre-sedimentation, flocculation, and sedimentation.

b. be constructed to permit units to be taken out of service without disrupting operation,

c. provide multiple-stage treatment facilities when required by the State to meet Federal Drinking Water Standards.

3.1.1 Presedimentation$^{(III-20)(I-60,Ks.)}$

Waters containing gravel, sand, silt, or turbidity in excess of 1,000 JTU may require pretreatment. Sedimentation, either with or without the addition of coagulation chemicals, is recommended.

a. Basin Design - Sedimentation basins should have hopper bottoms and/or be equipped with continuous mechanical sludge removal apparatus especially selected or designed to remove heavy silt or sand and should include provisions for rapid draining and hydraulic flushing.

b. Inlet - Incoming water should be dispersed across the full width of the line of travel as quickly as possible; short circuiting should be prevented.

c. Bypass - Provisions for bypassing sedimentation basins should be included.

d. Detention Time - Two hours detention is the minimum period recommended; greater detention may be required at the direction of the State.

e. Surface overflow rate, maximum recommended

143,000 liters/sq.M/day
(3,500 gals/sq.ft./day).

f. Water depth, minimum 2.5 meters (3 feet) is recommended.

g. Weir rate, maximum 236,000 liters per meter per day (19,000 gals/lineal ft./day) is recommended.

h. Drain lines, minimum diameter 20.3 cm (8 inches) recommended.

3.1.2 Mixing (Flash or Quick)(III-20)- Mixing means the rapid dispersion of chemicals throughout the water to be treated, by violent agitation.

a. Mechanical mixers, hydraulic jump, and Parshall flume may be approved. Baffled mixing chambers are not recommended and are acceptable only when provisions are made for proper mixing under anticipated variations in flow.

b. Mixing - The detention period should be not less than thirty seconds in mechanical mixing chambers. In-line mixers need less detention time.

3.1.3 Flocculation (slow mixing) Basins, Primary or Secondary(III-20)

a. Basin Design - Inlet and outlet design should prevent short circuiting and destruction of floc. Series compartments are recommended to prevent short-circuiting and to provide decreasing mixing energy with time. A drain should be provided.

b. Detention - Minimum flow-through velocity should be not less than 0.61 nor greater than 1.83 M/sec. (0.5 nor greater than 1.5 feet per second) with a recommended time for floc formation of at least 30 minutes.

c. Mean Velocity Gradient (G). G values of 20 to 70 sec^{-1} are recommended. Flocculation in 3 basins in series is suggested with G values of 50-100, 5-50, and 1-10 in basins 1, 2, and 3 respectively.

d. Equipment - Agitators should be driven by variable speed drives with the peripheral speed of paddles ranging from 0.15 to 0.61 meters/second (0.5 to 2.0 feet per second). External, non-submerged drive equipment is preferred. Cross-flow, axial-flow, propeller, or turbine type equipment is acceptable.

e. Piping - Flocculation and sedimentation basins should be as close together as possible. The velocity of flocculated water through pipes or conduits to settling basins should be not less than 0.61 nor greater than 1.82 M/sec (0.5 nor greater than 1.5 feet per second). Allowances should be made to minimize turbulence at bends and changes in direction.

f. Other designs - Baffling may be used to provide for flocculation in small plants only after consultation with the State. The design should be such that the velocities and flows noted above will be maintained.

3.1.4 Sedimentation (III-20)(I-60,Ks.)

The requirements for effective clarification are dependent upon a number of factors related to basin design and the nature of the raw water (turbidity, color and colloidal matter, taste and odor causing compounds, or other material to be removed). Also to be considered is the character of floc formed.

a. Inlet Devices - Inlets should be designed to distribute the water equally and at uniform velocities. Open ports, submerged ports, and similar entrance arrangements are recommended. A baffle should be constructed across the basin close to the inlet end and should project several feet below the water surface to dissipate inlet velocities and provide uniform flows across the basin.

b. Outlet Devices - Outlet devices should be designed to maintain velocities suitable for settling in the basin and to minimize shortcircuiting. The use of submerged orifices is recommended in order to make the volume above the orifices available for storage of any excess of water pumped to the plant beyond that passed through the filters.

c. Overflow Rate - The recommended maximum surface overflow rate is 25,000 l/day/sq.m. (600 gpd/sq. ft.) and the rate of flow over the outlet weir should not exceed 248,000 L/day/M (20,000 gallons per day per foot) of weir length. Where submerged ports are used as an alternate for overflow weirs, they should be not lower than 0.9 meters (3 feet) below the flow line.

d. Drainage - Basins should be provided with a means for dewatering. Basin bottoms should slope toward the drain not less than one in twelve where mechanical sludge collection equipment is not required. Minimum diameter drain line is 20.32 cm (8 inches).

e. Covers - Covers are acceptable at certain plant locations: however, where basins have mechanical equipment, a superstructure should be provided in place of a cover. Where covers are used, manholes should be provided as well as drop light connections so that observation of the floc can be made at several points within the basin.

f. Velocity - The velocity through settling basins should not exceed 0.15 meter (0.5 feet) per minute. The basins should be designed to minimize shortcircuiting. Baffles should be provided as necessary.

g. Overflow - An overflow weir (or pipe) should be installed which will establish the maximum water level desired on top of the filters. It should discharge with a free fall at a location where the discharge will be seen.

h. The minimum horizontal distance from basin inlet to outlet should be 3 meters (10 feet) except as approved by the State.

i. Safety - Permanent ladders or handholds should be provided for safety on the inside walls of basins above the water level. Guard rails should be included. Flushing lines or hydrants should not include interconnection of the potable water with non-potable water.

j. Sludge Collection - Mechanical sludge collection equipment should be provided.

k. Sludge Disposal - Facilities are required by the State for disposal of sludge. Provision should be made for operator to observe or sample sludge being withdrawn from unit.

3.1.5 Solids Contact Units(II-20)

Units are acceptable for combined softening and clarification where water characteristics are not variable and flow rates are uniform. Before such units are considered as clarifiers without softening, specific approval of the State shall be obtained. Clarifiers should be designed for the maximum uniform rate and should be adjustable to changes in flow which are less than the design rate and for changes in water characteristics. A minimum of two units is recommended.

3.1.5.1 Installation of Equipment - Supervision by a representative of the manufacturer should be provided with regard to all mechanical equipment at the time of

a. installation, and

b. initial operation.

3.1.5.2 Operating Equipment - The following should be provided for plant operation:

a. a complete outfit of tools and accessories,

b. necessary laboratory equipment,

c. adequate piping with suitable sampling taps so located as to permit the collection of samples of water from critical portions of the units.

3.1.5.3 Chemical Feed - Chemicals should be applied at such points and by such means as to insure satisfactory mixing of the chemicals with the water.

3.1.5.4 Mixing - Mixing devices employed should be so constructed as to

a. provide good mixing of the raw water with previously formed sludge particles, and

b. prevent deposition of solids in the mixing zone.

3.1.5.5 Flocculation - Flocculation equipment

a. should be adjustable,

b. should provide for coagulation to occur in a separate chamber or baffled zone within the unit,

c. should provide the flocculation and mixing period to be not less than 30 minutes.

3.1.5.6 Sludge Concentrators and Recirculation - The equipment should provide either internal or external recirculation and concentrators in order to obtain a concentrated sludge with a minimum of waste water.

3.1.5.7 Sludge Removal - Sludge removal design should provide that

a. sludge pipes shall be not less than 7.6 cm (three inches) in diameter and so arranged as to facilitate cleaning,

b. entrance to sludge withdrawal piping should prevent clogging,

c. valves should be located outside the tank for accessibility,

d. operator may observe or sample sludge being withdrawn from the unit.

3.1.5.8 Cross-Connections

a. blow-off outlets and drains should terminate and discharge at places satisfactory to the State.

b. cross-connection control should be included for the potable water lines used to backflush sludge lines.

3.1.5.9 Detention Period - The detention time should be established on the basis of the raw water characteristics and other local conditions that affect the operation of the unit.

3.1.5.10 Suspended Slurry Concentrate - Softening units should be designed so that continuous slurry concentrates of one per cent or more, by weight, can be satisfactorily maintained.

3.1.5.11 Water Losses -

a. units should be provided with suitable controls for sludge withdrawals,

b. total water losses should not exceed,

   1. 5 percent for clarifiers

   2. 3 percent for softening units,

c. solids concentration of sludge bled to waste should be

   1. 3 percent by weight for clarifiers

   2. 5 percent by weight for softeners.

3.1.5.12 Weirs or Orifices - The units should be equipped with either overflow weirs or orifices. Weirs should be

a. adjustable,

b. at least equivalent in length to the perimeter of the tank,

c. constructed so that surface water does not travel over 3 meters (10 feet) horizontally to the collection trough.

3.1.5.13 Weir Loading -

a. weir loading should not exceed

   1. 250 liters per minute per meter (20 gallons per minute per foot) of weir length for units used for softeners,

   2. 125 liters per minute per meter (10 gallons per minute per foot) of weir length for units used for clarifiers.

b. orifices should produce uniform rising rates over the entire area of the tank.

3.1.5.14 Upflow Rates - Unless supporting data is submitted to the State to justify other rates, upflow rates should not exceed:

a. 71 liters per minute per square meter (1.75 gallons per minute per square foot) of area at the slurry separation line, for units used for softeners,

b. 41 liters per minute per square meter (1.0 gallon per minute per square foot) of area at the sludge separation line for units used for clarifiers.

3.1.6 Settling Tube Clarifiers(III-14)

Shallow depth sedimentation devices or tube clarifier systems of the essentially horizontal or steeply inclined types may be used under appropriate conditions.

3.1.6.1 Settling Tube Installations In Horizontal Flow Basins, Loading Rates.

		Settling Tube Installations In Horizontal Flow Basins Recommended Maximum Overflow Rates			
Water Temperature, Degrees C	Raw Water Turbidity Range, JU	Based on total clarifier surface area		Based on total area covered by tubes	
		Lpm/Sq.M	gpm/sf	Lpm/Sq.M	gpm/sf
Frequently	0-100	80	2	120	3
4 or lower	100-1,000	80	2	100	2.5
Usually above 4	0-100	120	3	140	3.5
	100-1,000	80	2	120	3

3.1.6.2 Settling Tube Installations In Solids Contact Units, Loading Rates.

Settling Tube Installations In
Solids Contact Units
Recommended Maximum Overflow Rates

Water Temperature, Degrees C	Based on total clarifier surface area		Based on total area covered by tubes	
	Lpm/Sq.M	gpm/sf	Lpm/Sq.M	gpm/sf
Frequently 4 or lower	80	2	120	3
Usually above 4	80	2	160	4
	100	2.5	100	2.5

3.1.6.3 Recommended Location of Tube Modules Within Basin

a. in zone of stable hydraulic conditions,

b. in areas nearest effluent launders in basins not completely covered by tubes,

c. top of tubes 0.6 M (2 feet) to 1.2 M (4 feet) below water surface.

3.1.6.4 Inlets and Outlets - See Section 3.1.4 a and 3.1.4 b for recommendations.

3.1.6.5 Tube Support Recommendations. The tube support system should be able to carry the weight of the tube modules when the basin is drained plus the weight of a workman standing on the tube modules, or not less than 36.6 Kg/Sq.M (7.5 lb/sf). The minimum bearing surface width of a support member should be 2.54 cm (1 inch), and support members should be located about 15.2 cm (6 inches) from the module end.

3.1.6.6 Tube Cleaning. Provisions should be made to drop water level occassionally for tube cleaning, or provide water or air jet cleaning system for top surface of tube modules.

3.2.0 Filtration (III-20)(III-18)(III-4)(III-3)

Acceptable filters include, at the discretion of the State, the following types:

a. rapid rate gravity filters,

b. rapid rate pressure filters, and

c. slow rate gravity filters.

The application of any one type should be supported by water quality data representing a reasonable period of time to characterize filter performance under variations in applied water quality. Experimental treatment studies may be required by the State to demonstrate the applicability of the method of filtration proposed to the water to be treated.

3.2.1 Rapid Rate Gravity Filters(III-20)

3.2.1.1 Pretreatment - The use of rapid rate gravity filters may require pretreatment.

3.2.1.2 Number - At least two units should be provided and, where the plant output is less than 380 Lpm (100 gallons per minute), each filter should be of plant capacity; provisions should be made to assure continuity of service with a filter unit temporarily removed from operation.

3.2.1.3 Rate of Filtration(III-20)(III-18)(III-3)

The permissible rate of filtration should be determined by the quality of the raw water, the degree of pre-treatment provided, the filter media provided and other considerations required by the State. The nominal rate for single media sand or coal filters is 82 Lpm/Sq.M (2 gpm/sf) and for approved mixed media (coal, sand, and garnet) or dual media (coal-sand) beds is 203.4 Lpm/Sq.M (5 gpm/sf) of filter area except as higher rates are justified by the designing engineer to the satisfaction of the State.

3.2.1.4 Structural Details and Hydraulics - The filter structure should be so designed as to provide for:

a. vertical walls within the filter;

b. no protrusion of the filter walls into the filter media;

c. cover by superstructure as determined necessary for temperature control or for intrusion protection where needed.

d. head room to permit normal inspection and operation;

e. minimum depth of filter box of 2.6 meters (8 1/2 feet);

f. minimum water depth over the surface of the media of 0.9 meters (3 feet);

g. trapped effluent to prevent backflow of air to the bottom of the filters;

h. prevention of floor drainage to the filter with a minimum 10 cm. (4 inch) curb around the filters;

i. prevention of flooding by providing overflow;

j. maximum velocity of treated water in pipe and conduits to filters of .6 Mps (2 feet per second);

k. cleanouts and straight alignments for influent pipes or conduits where solids loading is heavy, or following lime-soda softening;

l. washwater drain capacity to carry maximum flow;

m. walkways around filters, to be not less than 0.6 meters (24 inches) wide.

n. roof drains shall not discharge into the filters or basins or conduits preceding the filters.

3.2.1.5 Washwater Troughs - Washwater troughs should be so designed as to provide:

a. the bottom elevation above the maximum level of expanded media during washing;

b. the top elevation above the filter surface, not to exceed 0.76 meters (30 inches);

c. 5 cm. (2 inch) freeboard at the maximum rate of wash;

d. the top or edge to be level;

e. spacing so that each trough serves the same number of square meters of filter area;

f. maximum horizontal travel of suspended particles to reach trough not to exceed 0.9 meters (3 feet).

3.2.1.6 Filter Materials(III-3)(III-14)(III-20)

For rapid filters, coarse-to-fine beds of mixed or dual media are preferred over fine-to-coarse single media beds.

a. Sand for Single-Media Beds(III-20)

The media should be clean silica sand having

1. a depth of not less than 0.61 meter (24 inches) and generally not more than 0.76 M (30 inches),
2. an effective size of from 0.45 mm to 0.55 mm, depending upon the quality of the raw water, and

3. a uniformity coefficient not greater than 1.65.

A 7.6 cm (3 inch) layer of torpedo sand should be used as a supporting media for the filter sand; such torpedo sand shall have

1. an effective size of 0.8 mm to 2.0 mm, and

2. a uniformity coefficient not greater than 1.7.

b. Anthracite for Single-Media Beds (III-20)

Clean crushed anthracite or a combination of sand and anthracite may be considered on basis of experimental data specific to the project; such media should have

1. an effective size from 0.45 mm to 0.8 mm, and

2. a uniformity coefficient not greater than 1.7.

c. Gravel (III-20)

Gravel, when used as the supporting media, should consist of hard, rounded particles and should not include flat or elongated particles. The coarsest gravel should be 6.35 cm (2 1/2 inches) in size when the gravel rests directly on the strainer system, and should extend above the top of the perforated laterals or strainer nozzles. Not less than four layers of gravel should be provided in accordance with the following size and depth distribution:

Size		Depth	
cm	inches	cm	inches
6.35 to 3.81	2 1/2 to 1 1/2	12.7 to 20.3	5 to 8
3.81 to 1.9	1 1/2 to 3/4	7.6 to 12.7	3 to 5
1.9 to 0.5	1/2 to 3/16	5.1 to 7.6	2 to 3
0.5 to 0.24	3/16 to 3/32	5.1 to 7.6	2 to 3

Reduction of gravel depths may be considered upon acceptable justification to the State when proprietary filter bottoms are installed.

d. Mixed Media (III-14)

Filter beds of this type typically contain a 0.76 meter (30 inch) depth of fine media made up of 42 cm (16.5 inches) of anthracite coal, specific gravity 1.5; 23 cm (9 inches) of silica sand, specific gravity 2.6; and 11.4 cm (4 1/2 inches) of garnet sand or ilemite, specific gravity 4.2 - 4.5. Other bed depths and distribution of the media may be required by the State. The relative size of the particles should be such that hydraulic grading of the material during backwash will result in a filter bed with pore space graded progressively from coarse to fine in the direction of filtration (down). The total surface area of all the grains of fine media in a 0.76 meter (30 inch) deep bed should be not less than 2,650 square millimeters for each square millimeter of filter plan area. The number of grains of fine media per square millimeter of plan area should be not less than 2,750. Core samples of the completed backwashed filter bed should show the number of grains per cubic millimeter as shown in the following table which illustrates a typical filter design:

Depth in Bed		Number of Grains Per Cubic Millimeter
cm	Inches	
Top 7.6	Top 3	0.5 to 8.0
7.6 - 23	3 - 9	0.4 to 3.0
23 - 38	9 - 15	0.4 to 3.0
38 - 46	15 - 18	0.4 to 8.0
46 - 53	18 - 21	0.7 to 8.0
53 - 61	21 - 24	5.0 to 10
61 - 68	24 - 27	5.0 to 15
68 - 76	27 - 30	5.0 to 15

When filtering alum coagulated and settled water having a turbidity of 20 JU (Jackson Units) at the rate of 203 Lpm/Sq.M (5 gpm/sq. ft.), the filter should produce an effluent having an average turbidity of less than 0.2 JU. Even when the filter rate is suddenly changed from 81 to 203 Lpm/Sq.M (2 to 5 gpm per square foot) the turbidity should not exceed 0.5 JU. The initial head loss in a 30 inch deep clean filter should not exceed 0.5 meter (1.6 feet) at a filter rate of 203 Lpm/Sq.M (5 gpm/sf) and at a water temperature of 20^{o}C. The time required to reach a total head loss of 3 meters (10 feet) terminal head loss, under the above conditions should be not less than 8 hours.

The mixed media should be supported on two layers of special high density gravel placed above the conventional silica gravel supporting bed. The special gravel should have a specific gravity not less than 4.2. The bottom layer should consist of particles passing No. 5 and retained on No. 12 U.S. mesh sieves and should be 3.8 cm (1 1/2 inches thick). The top layer should consist of particles passing No. 12 and retained on No. 20 U.S. mesh sieves, and should be 3.8 cm (1 1/2 inches) thick.

e. Dual Media(III-14)

Coal-sand filters should consist of a coarse coal layer - typically about 46 cm (18 inches) thick - above a layer of fine sand - typically 21 cm (8 inches) thick. Some mixing of coal and sand at their interface is desirable.

The coal and sand distribution by sieve size in dual media should be as follows (unless otherwise approved by the State):

Coal Distribution by Sieve Size

U.S. Sieve No.	Percent Passing Sieve
4	99 - 100
6	95 - 100
14	60 - 100
16	30 - 100
18	0 - 50
20	0 - 5

Sand Distribution by Sieve Size

20	96 - 100
30	70 - 90
40	0 - 10
50	0 - 5

3.2.1.7 Restricted Declining Flow Rate Filters. Units of this type may be used subject to State approval. Submit data on method proposed to limit maximum flow rate.

3.2.1.8 Filter Bottoms and Strainer Systems(III-20)

Porous plate bottoms should not be used where iron or manganese may clog them or with waters softened by lime. The design of manifold type collection systems should be such as to:

a. minimize loss of head in the manifold and laterals;

b. assure even distribution of washwater and even rate of filtration over the entire area of the filter;

c. provide the ratio of the area of the final openings of the strainer systems to the area of the filter at about 0.003;

d. provide the total cross-sectional area of the laterals at about twice the total area of the final openings;

e. provide the cross-sectional area of the manifold at 1 1/2 to 2 times the total area of the laterals.

The State should be consulted when proprietary bottoms vary from the above guidelines.

3.2.1.9 Surface Wash(III-20) - Surface wash facilities are recommended and may be accomplished with a 3.8 to 5 cm (1 1/2 to 2 inch) pressure line conveniently located to the filter plant operating floor and including a suitable length of 2.5 to 3.8 cm (1 inch to 1 1/2 inch) pressure hose and nozzle. A system of fixed nozzles or a revolving type apparatus may also be used. All surface wash devices should be designed with:

a. provisions for water pressures of 3 to 5.3 Kg/Sq. cm (45 to 75 psi);

b. a vacuum breaker or other device to prevent back siphonage;

c. suitable rack for storage of hoses and other equipment;

d. use of filtered water, or air and filtered water.

3.2.1.10 Appurtenances(III-20)

The following should be provided for every filter:

a. sampling tap,

b. indicating and recording loss of head gauge,

c. indicating and recording flow rate control; a modified rate controller which limits the rate of filtration to a maximum rate may be used, however, equipment that simply maintains a constant water level on the filters is not acceptable, unless the rate of flow onto the filter is properly controlled; a pump in each filter effluent line may also be used as the limiting factor for the rate of filtration only after consultation with the reviewing authority.

d. provisions for operating and draining the filter to waste with appropriate measures for backflow prevention.

e. means for feeding polymer as a filter aid at a controlled rate to filter influent water.

f. indicating and recording effluent turbidimeter accurately reading to 0.1 JU or less.

3.2.1.11 Backwash(III-20)

Provisions should be made for washing sand, dual-media, and mixed media filters as follows:

a. minimum rate of 610 Lpm/Sq.M (15 gallons per square foot) per minute, consistent with water temperatures and specific gravity of the filter media; a rate of 814 Lpm/Sq.M (20 gallons per square foot) per minute to provide for a 50 percent expansion of the sand bed is recommended;

b. filtered water provided at the required rate by washwater tanks, washwater pumps, from the high service main, or a combination of these;

c. washwater pumps in duplicate unless an alternate means of obtaining washwater is available;

d. not less than 15 minute wash of one filter at the design rate of wash;

e. washwater regulator or valve on the main washwater line to obtain the desired rate of filter wash with the washwater valve on each individual filter open wide;

f. rate-of-flow indicator and recorder on the main washwater line, located so that it can be easily read by the operator during the washing process;

g. means provided to prevent accumulation of air in filter washwater supply piping and pump between backwashes.

3.2.2 Rapid Rate Pressure Filters(III-20)

The use of these filters may be considered for iron and manganese removal and other clarification processes consistent with 3.2 above. Pressure filters shall not be used in the filtration of polluted waters or following lime-soda softening.

3.2.2.1 General - Recommended minimum criteria relative to number, rate of filtration, structural details and hydraulics, filter media, etc., described above for rapid rate gravity filters also apply to pressure filters where appropriate.

3.2.2.2 Rate of Filtration - The nominal rate should be 81 Lpm/Sq.M (2 gallons per minute per square foot) of filter area for single media beds, and 203 Lpm/Sq. M (5 gpm/sf) for mixed media or dual media beds.

3.2.2.3 Details of Design - The filters should be designed to provide for:

a. indicating and recording loss of head gauges on the inlet and outlet pipes of each filter;

b. a flow indicator and recorder for each filtering unit;

c. filtration and backwashing of each filter individually with an arrangement of piping as simple as possible to accomplish these purposes;

d. minimum side wall height of 1.5 meters (5 feet); a corresponding reduction in side wall height is acceptable where proprietary bottoms permit reduction of the gravel depth;

e. the top of the washwater collection trough to be at least 46 cm (18 inches) above the surface of the filter media.

f. the underdrain system to collect efficiently the filtered water and to distribute the backwash water at a rate not less than 610 Lpm/Sq.M (15 gallons per minute per square foot) of filter area;

g. location of flow indicators and controls that is easily readable while operating the control valves;

h. air release valve on the highest point of each filter;

i. accessible manhole to facilitate inspections and repairs;

j. means to observe the wastewater during backwashing;

k. construction to prevent cross-connections;

l. surface wash facilities including external rotation indicator are required;

m. feeding polymer as a filter aid at a controlled rate to filter influent water

n. indicating and recording effluent turbidimeter accurately reading to 0.1 JU or less for each filter.

3.2.3 Slow Rate Gravity Filters(III-20)

The use of these filters should be preceded by engineering studies to demonstrate the adequacy and suitability of this method of filtration for the specific raw water supply.

3.2.3.1 Quality of Raw Water - Slow rate gravity filtration should be limited to waters having maximum turbidities of 50 JU and maximum color of 30 units; such turbidity must not be attributable to colloidal clay. Raw water quality data should include examinations for algae, because the fine sand used in slow rate filters is particularly susceptible to plugging by algae.

3.2.3.2 Structural Details and Hydraulics - Slow rate gravity filters should be so designed as to provide:

a. not less than two filter units;

b. cover as determined necessary for the temperature control, exclusion of sunlight, or protection from intrusion.

c. headroom to permit normal movement by operating personnel for scraping and sand removal operations;

d. adequate manholes and access ports for handling of sand;

e. filtration to waste and overflow at the maximum filter water level.

3.2.3.3 Rates of Filtration - The permissible rates of filtration should be determined by the quality of the raw water and on the basis of specific experimental data derived for the water to be treated. The nominal rate may be 1,830 to 6,110 Lpd/Sq.M (45 to 150 gallons per day per square foot) of sand area, with rates of 6,110 to 9,370 Lpd/Sq.M (150 to 230 gallons per day per square foot) acceptable when demonstrated to the satisfaction of the State.

3.2.3.4 Underdrains - Each filter unit should be equipped with a main drain and an adequate number of lateral underdrains to collect the filtered water. The underdrains should be so spaced that the maximum velocity of the water flow in the lateral underdrain will not exceed 0.225 Mps (0.75 feet per second). The maximum spacing of the laterals should not exceed 3.66 M (12 feet).

3.2.3.5 Filtering Material

a. filter sand should be placed and maintained on graded gravel layers for a minimum depth of 0.76 meters (30 inches);

b. the effective size should be between 0.35 mm and 0.50 mm;

c. the uniformity coefficient should not exceed 2.5;

d. the sand should be clean and free from foreign matter.

3.2.3.6 Filter Gravel - The supporting gravel should conform to the size and depth distribution provided for rapid rate gravity filters.

3.2.3.7 Depth of Water on Filter Beds - Design should provide a depth of at least 0.9 to 1.5 meters (3 to 5 feet) of water over the sand. Influent water should not scour the sand surfaces.

3.2.3.8 Control Appurtenances - Each filter should be equipped with:

a. loss of head gauge;

b. an orifice, Venturi meter, or other suitable metering device installed on each filter to control the rate of filtration;

c. an effluent pipe located with the invert at an elevation above the top of the sand (to maintain water level above sand).

3.2.4 Diatomaceous Earth Filtration(III-105)

Installation of diatomaceous earth filtration should not be made without a pilot plant study on the water to be treated. All conditions of the study, and the results, must be acceptable to the State before plans for a final installation are made.

Commercial diatomaceous earth filters now on the market appear to be satisfactory for filtering water of low turbidity with low bacterial contamination.

They are not satisfactory for:

1. Bacterial removal.
2. Color removal.
3. Removal of certain types, or any large amounts, of materials which cause turbidity.
4. Filtering water with high algae counts.

The type of material to be removed by a diatomaceous earth filter as well as the amount are critical to its effective operation. Some plants have had short filter runs when turbidities exceeded 5 JU.

More finished water storage than that normally provided is required with diatomaceous earth filters to provide continuity of service to the system during adverse raw water conditions that require frequent back-washing of the filters.

There are certain advantages in having an open vacuum-type diatomaceous earth filtration unit which is designed to permit observation of the filter surfaces to determine proper cleaning, damage to the filter elements, and adquate coating without holidays. Filter-to-waste connections, and/or recirculation facilities, are a necessity. Pressure diatomaceous earth is better for filtration of near freezing waters with high D.O. content.

Diatomaceous earth filtration can be used for iron removal from well water if the removal is effective and the well water is of safe sanitary quality before treatment.

3.2.5 Granular Carbon as a Filter Material(III-14)

Activated carbon is beneficial in removing organic substances and in the control of tastes and odors in public water supplies. Granular activated carbon can be used in two ways: (1) as a filter media, as covered by this Section, or (2)in carbon contactors as another treatment step separate from filtration, as covered by Section (3.9) of this Manual.

Where granular activated carbon is proposed as a filter material, the State shall be consulted concerning the applicability of the proposal. Such a proposal should include:

1. Criteria for the media which meets Section 3.2.1.6 e (coal for dual-media filters).

2. Provision for disinfection of the water following the filters and prior to distribution.

3. Specifications for a periodic treatment of filter material which will control possible bacterial and other growths.

4. An engineering report covering raw water quality and design criteria.

3.3.0 Disinfection

Disinfection is recommended for all surface water supplies and all ground water supplies.

Ozone and chlorine are acceptable disinfection agents under certain conditions.

It is suspected that there are relationships between substances formed by reaction of chlorine with natural organic materials (such as humic substances, which are ubiquitous) or with synthetic organic materials (from pollution) and the incidence of certain types of cancer in water drinkers. Because of this potential hazard to health, it is desirable either to: (1) eliminate or minimize the production of these chloro-organic compounds by removal of organic compounds from the water prior to chlorination, or (2) remove insofar as possible, the chloro-organic compounds from the water following chlorination.

Candidate methods for removal of organics or chloro-organic compounds from water are carbon adsorption, coagulation, and filtration.

3.3.1 Chlorination Equipment(III-20)

3.3.1.1 Type - Solution-feed-gas-type chlorinators and hypochlorite feeders of the positive displacement type are acceptable.

3.3.1.2 Capacity - The chlorinator capacity should be such that a free chlorine residual of at least 2 mg/l can be attained in the water after a contact time of at least 30 minutes when maximum flow rates coincide with anticipated maximum chlorine demands. The equipment should be of such design that it will operate accurately over the desired feeding range. Exceptions to this requirement should be approved by the State.

3.3.1.3 Standby Equipment - Where chlorination is necessary for protection of the supply, standby equipment of sufficient capacity should be available to replace the largest unit during shut-downs.

3.3.1.4 Automatic Proportioning - Automatic proportioning chlorinators may be required where the rate of flow either is not reasonably constant or where the rate of flow of the water is not manually controlled.

3.3.1.5 Contact Time and Point of Application - Chlorine should be applied at a point which will provide the maximum contact time, generally not less than one hour. Consideration should be given to the minimizing of short-circuiting. At plants treating surface water, provisions should be made for applying chlorine to the raw water for taste and odor control, to filter influent for control of slime growths on filter media, and to filter effluent and high lift pump suction for disinfection. At plants treating ground water, provision should be made for applying chlorine to the clearwell inlet and the high-lift pump suction.

3.3.1.6 Residual Testing Equipment - The equipment shall enable measurement of residuals to the nearest 0.1 mg/l in the range below 0.5 mg/l and to the nearest 0.2 mg/l between 0.5 mg/l to 1.0 mg/l. Automatic chlorine residual recorders are recommended where the chlorine demand varies appreciably over a short period of time.

3.3.1.7 Housing - Adequate housing should be provided for the chlorination equipment and for chlorine in storage.

3.3.2 Ozonation Equipment(III-14)

Ozone is unstable and rapidly decomposes back to oxygen and must be generated on-site as needed at the point of water treatment.

3.3.2.1 Type - Ozone generators of the plate or tubular electrode and dielectric design are acceptable. The equipment should include air blower and filter, air cooling system (refrigeration unit or water cooled heat exchanger), air drying (silica gel or calcium chloride dessicator), and other necessary auxiliaries.

3.3.2.2 Capacity - The ozonator capacity should be such that a residual of at least 2 mg/l can be attained in the water after a contact time of at least 30 minutes when maximum flow rates coincide with anticipated maximum ozone demands. The equipment should be of such design that it will operate accurately over the desired feeding range. Exceptions to this requirement must be approved by the State.

3.3.2.3 Standby Equipment - Standby equipment of sufficient capacity should be available to replace the largest unit during shut-downs.

3.3.2.4 Automatic Proportioning - Automatic proportioning ozonators are desirable to the extent possible where the rate of flow either is not reasonably constant or where the rate of flow of the water is not manually controlled.

3.3.2.5 Application - Ozone may be applied to the water directly as a gas or by an injector system similar to a chlorine injector system. In gas applications, depth of submergence, bubble size and difussion, mixing, baffling, and other conditions should be such as to assure maximum solution of the ozone in the water.

3.3.2.6 Contact Time and Point of Application - Ozone should be applied at a point which will provide the maximum contact time, generally not less than 30 minutes. Consideration should be given to the minimizing of short circuiting. At plants treating surface water, provisions should be made for applying ozone to the raw water, applied water, filtered water and/or the high-lift pump suction. At plants treating ground water, provision should be made for applying ozone to the clearwell inlet and the high-lift pump suction.

3.3.2.7 Residual Testing Equipment - The equipment should enable measurement of residuals to the nearest 0.1 mg/l in the range below 0.5 mg/l and to the nearest 0.2 mg/l above 0.5 mg/l.

3.3.2.8 Ozonator Piping - The water supply piping to the ozonator should be designed to prevent contamination of the treated water supply by sources of questionable quality.

3.3.2.9 Housing - Adequate housing should be provided for the ozone equipment.

3.3.2.10 Residual - In order to maintain a residual disinfectant in water in the distribution system, the State may require that ozonation be followed by chlorination treatment.

3.3.3 Ultraviolet Irradiation

There is evidence to indicate that ultraviolet irradiation, when applied under optimum conditions to a water meets the chemical and physical standards of the Federal Drinking Water Standards before the ultraviolet treatment, will produce a safe potable water.

A properly designed and installed ultraviolet unit, given adequate supervision and maintenance, is satisfactory for providing disinfection to water from a well which meets the requirements of the State for location and construction.

Since the water in a distribution system beyond the point of disinfection may be subject to bacterial contamination, a residual disinfectant is recommended in drinking water supplies. If ultraviolet irradiation is used in such cases, it must be followed by halogen treatment to provide the necessary residual as required by the State.

Because of the numerous safeguards required in an acceptable ultraviolet unit and in its installation, the supervision and maintenance necessary for proper operation, the potential of substances common in many waters that interfer with ultraviolet disinfection, and the lack of a simple quick test of the finished water for effective treatment, ultraviolet irradiation is not recommended for general use in the disinfection of public water supplies. Use of the process should be approved by the State.

3.4.0 Softening (III-20)

The softening process selected should be based upon the mineral qualities of the raw water and the desired finished water quality (total hardness about 100 mg/l as $CaCO_3$) in conjunction with requirements for disposal of sludge or brine waste, cost of plant, cost of chemicals and plant location. Applicability of process chosen should be demonstrated to the State.

3.4.1 Lime-Soda Process - The applicable design standards for mixing, flocculation and sedimentation are the same for the lime-soda process as for conventional clarification except that the minimum settling time is two hours. Where softening is included as a treatment process in conjunction with clarification, the clarification criteria shall govern. See 3.1.2, 3.1.3, 3.1.4. For criteria pertaining to softening with solids contact units see 3.1.5.

3.4.1.1 Equipment - Mechanical sludge removal equipment should be provided in the sedimentation basin. See 3.11 for sludge disposal.

3.4.1.2 Aeration - Determinations should be made in the field for the CO_2 content of the raw water. When concentrations exceed 10 milligrams per liter, the economics of removal by aeration as opposed to removal with lime should be considered. See 3.5.

3.4.1.3 Stabilization - Equipment for stabilization of water softened by the lime-soda process is required. See 3.8 for stabilization.

3.4.1.4 Sludge Disposal - Provisions must be included for proper disposal of softening sludges. See 3.11 and 1.6. Recycling of reclaimed lime should be considered.

3.4.1.5 Disinfection - The use of excess lime should not be considered an acceptable substitution for any approved method of disinfection. See 3.3.

3.4.2 Cation Exchange Process - Iron, manganese, or a combination of the two, in the oxidized state or unoxidized state, should not exceed 0.3 milligrams per liter in the water as applied to the ion exchange material. Pretreatment is required when the content of iron, manganese, or a combination of the two, is one milligram per liter or more.

3.4.2.1 Design - The units may be of pressure or gravity type, of either an upflow or downflow design, using automatic or manual regeneration. Automatic regeneration is suggested for small plants.

3.4.2.2 Exchange Capacity - The design capacity for hardness removal should not exceed 20,000 grains per cubic foot when resin is regenerated with 136 gms (0.3 pounds) of salt per kilograin of hardness removed.

3.4.2.3 Depth of Media - The depth of the exchange material should not be less than 0.9 meters (3 feet).

3.4.2.4 Flow Rates - The rate of softening should not exceed 285 Lpm/Sq.M (7 gallons per square foot) per minute and the backwash rate should be 245 to 326 Lpm/Sq.M

(6 to 8 gallons per square foot) per minute.

3.4.2.5 Freeboard - The freeboard will depend upon the specific gravity of the media and the direction of water flow.

3.4.2.6 Underdrains and Supporting Gravel - The bottoms, strainer systems and support for the exchange material should conform to criteria provided for rapid rate gravity filters. See 3.2.1.6 and 3.2.1.7.

3.4.2.7 Brine Distribution - Facilities should be included for even distribution of the brine over the entire surface of both upflow or downflow units. Backwash, rinse and air relief discharge pipes should be installed in such a manner as to prevent any possibility of back-siphonage.

3.4.2.8 Bypass - A bypass should be provided around softening units to produce a blended water of desirable hardness. Meters should be installed on the bypass line and on each softener unit. An automatic proportioning or regulating device and shut-off valve should be provided on the bypass line. In some installations it may be necessary to treat the bypassed water to obtain acceptable levels of iron and/or manganese in the finished water.

3.4.2.9 Additional Limitations - Waters having 5 JU or more turbidity should not be applied directly to the cation exchange softener. Silica gel materials should be used for waters having a pH above 8.4 and should not be used when iron is present. When the applied water contains a chlorine residual the cation exchange material shall be a type that is not damaged by residual chlorine. Phenolic resin should not be used.

3.4.2.10 Sampling Taps - Smooth-nose sampling taps should be provided for the collection of representative samples for both bacteriological and chemical analyses. The taps should be located to provide for sampling of the softener influent, softener effluent and the blended water. The sampling taps for the blended water should be at least 6 meters (20 feet) downstream from the point of blending.

3.4.2.11 Brine and Salt Storage Tanks - Brine measuring or salt dissolving tanks and wet salt storage facilities should be covered. The make-up water inlet should have a free fall discharge of two pipe diameters above the maximum liquid level of the unit or be protected from back-siphonage. Water for filling the tank should be distributed over the entire surface by pipes above the maximum brine level in the tank. The salt should be supported on graduated layers of gravel under which is a suitable means of collecting the brine. Wet salt storage basins should be equipped with manhole or hatchway openings having raised curbs and watertight covers having overhanging edges similar to those recommended for finished water reservoirs. Overflows, where provided, should be turned down, have a proper free fall discharge and be protected with noncorrodible screens or self-closing flap valves.

3.4.2.12 Storage Capacity - Wet salt storage basins should have sufficient capacity to store in excess of 1 1/2 carloads or truckloads of salt, and to provide for at least 30 days of operation.

3.4.2.13 Stabilization - Stabilization for corrosion control should be provided. See 3.8.

3.4.2.14 Waste Disposal - Suitable disposal should be provided for brine waste. See 3.11.

3.4.2.15 Construction Material - Pipes and contact materials should be resistant to the aggressiveness of salt.

3.4.2.16 Housing - Salt storage tanks and feed equipment should be enclosed and separated from other operating areas in order to prevent damage to equipment.

3.5.0 Aeration (III-20)

Aeration treatment devices as described herein may be used for oxidation, separation of gases, or for taste and odor control.

3.5.1 Natural Draft Aeration - Design should provide that

a. water is distributed uniformly over the top tray;

b. water is discharged through a series of three or more trays with separation of trays not less than 15 cm (6 inches);

c. trays are loaded at rates of 40 to 200 Lpm/Sq.M (1 to 5 gpm for each square foot) of total tray area;

d. trays have slotted, woven wire cloth or perforated bottoms;

e. perforations are 0.5 to 1.25 cm (3/16 to 1/2 inches) in diameter, spaced 2.5 to 7.6 cm (1 to 3 inches) on centers, when perforations are used;

f. 20 to 30 cm (8 to 12 inches) of inert media, such as coke or limestone, that will not disintegrate due to freezing cycles, is used in trays;

g. aerated water receives disinfection treatment.

3.5.2 Forced or Induced Draft Aeration - Devices should be designed to

a. provide adequate countercurrent of air through enclosed aeration column;

b. be such that air introduced into column passes through insect-tight screen and is as free of dust as possible;

c. insure that water outlet is adequately sealed to prevent unwanted loss of air;

d. be such that sections of the aerator can be easily reached and removed for maintenance.

3.5.3 Pressure Aeration - This method may be used for oxidation purposes if pilot plant study indicates method is applicable; it is not acceptable for removal of dissolved gases. Filters following pressure aeration should have adequate exhaust devices for release of air. Pressure aeration devices should be designed to:

a. give thorough mixing of compressed air with water being treated;

b. provide screened and filtered air, free of obnoxious fumes, dust, dirt, and other contaminants.

3.5.4 Other Methods of Aeration - Other methods of aeration may be used if applicable to the treatment needs. Such methods include but are not restricted to spraying, diffused air, and mechanical aeration. The treatment processes must be designed to meet the particular needs of the water to be treated and are subject to the approval of the State.

3.5.5 Protection from Wind - Aerators that discharge through the atmosphere should be protected by being placed in a louvered enclosure so designed as to provide easy access to the interior.

3.5.6 Protection from Contamination - Aerators that are used for oxidation or removal of dissolved gases from waters that will be given no further treatment other than chlorination should be protected from contamination from insects and birds.

3.5.7 By-Pass - A by-pass should be provided for all aeration units.

3.6.0 Iron and Manganese Control (III-20)

Iron and manganese control, as used herein, refers solely to treatment processes designed specifically for this purpose. The treatment process used will depend upon the character of the raw water. The selection of one or more treatment processes should meet specific local conditions as determined by engineering investigations, including chemical analyses of representative samples of water to be treated, and receive the approval of the State. It may be advisable to operate a pilot plant in order to gather all information pertinent to the design.

3.6.1 Removal by Oxidation, Detention and Filtration

3.6.1.1 Oxidation - Oxidation may be by aeration, as indicated in 3.5, or by chemical oxidation with chlorine, potassium permanganate, or ozone.

3.6.1.2 Detention - A minimum detention of 20 minutes shall be provided following oxidation by aeration in order to allow time for completion of oxidation reactions. This minimum detention should be omitted only where a pilot plant study indicates no need for detention. The detention basin should be designed as a holding tank with no provisions for sludge collection but with sufficient baffling to prevent short circuits. Sedimentation basins should be provided when treating water with high iron and/or manganese content or where chemical coagulation is used in order to reduce the load on the filters.

3.6.1.3 Filtration - Filters should conform to 3.2.

3.6.2 Removal by Lime-Soda Process - See 3.4.1.

3.6.3 Removal by Units Using Continuous Potassium Permanganate "Regeneration" - This process, consisting of a continuous feed of potassium permanganate to the influent of a manganese greensand filter, is more applicable to the removal of manganese than to the removal of iron, due to economic considerations.

a. The permanganate should be applied as far ahead of the filter as practical.

b. Other oxidizing agents or processes such as chlorination or aeration may be used prior to the permanganate feed to reduce the cost of the chemical.

c. Normal filtration rate is 122 Lpm/Sq.M (3 gpm per sq. ft.).

d. Normal wash rate is 326 to 407 Lpm/Sq.M (8 to 10 gpm per sq. ft.).

e. Air washing should be provided.

f. Sample taps should be provided

   1. prior to application of permanganate;

   2. immediately ahead of filtration;

3. at point between anthracite coal media and the manganese treated greensand;

4. halfway down the manganese treated greensand;

5. for filter effluent.

3.6.4 Removal by Ion Exchange - This process of iron and manganese removal should not be used for water containing more than 1.0 mg/l of iron, manganese or combination thereof. This process is not acceptable where either the raw water or wash water contains dissolved oxygen.

3.6.5 Sequestration - This process is generally suitable only for low contents of iron and manganese, generally 1.0 mg/l or less. The dosage should not exceed 10 mg/l. Where phosphate treatment is used, satisfactory chlorine residuals should be maintained in the distribution system.

a. Feeding equipment shall conform to requirements of Section IV.

b. Stock phosphate solution should be kept covered and disinfected by carrying approximately 10 mg/l chlorine residual.

c. The point of application should be prior to any aeration or oxidation if no iron or manganese removal treatment is provided.

d. Phosphate chemicals should be food grade.

3.6.6 Sampling Equipment - Smooth-nosed sampling taps should be provided for control purposes. Taps should be located on each raw water source, each treatment unit influent, and each treatment unit effluent.

3.6.7 Testing Equipment - Testing equipment should be provided for all plants. The equipment should have the capacity to accurately measure the iron content to a minimum of 0.1 mg/l and the manganese content to 0.05 mg/l.

3.7.0 Fluoridation (III-250)(III-20) and Defluoridation (III-254)

The optimum fluoride content of drinking water is sensitive to the annual average of the maximum daily air temperatures for the location of the public water system, see the Interim Primary Drinking Water Standards for these values.

Commercial sodium fluoride, sodium silicofluoride, and hydrofluosilicic acid should conform to the AWWA Standards for these materials. Other chemicals which may be made available should be approved by the

State.

3.7.1 Fluoride Compound Storage - Compounds should be stored in covered or unopened shipping containers. Storage units for hydrofluosilicic acid should be vented to the atmosphere at at point outside any building.

3.7.2 Dry Conveyors - Provision should be made for the proper transfer of dry fluoride compounds from shipping containers to storage bins or hoppers, in such a way as to minimize the quantity of fluoride dust.

3.7.3 Chemical Feed Installations should

a. conform to Section IV;

b. provide scales or loss-of-weight recorders for dry chemical feeds;

c. have an accuracy that actual feed will be within five percent of that intended;

d. be such that the point of application of hydrofluosilicic acid, if into a pipe, shall be in the lower half of the pipe and project upward.

e. be such as to provide a minimum of 20 strokes per minute at feeding rate, where fluoride is fed directly to the distribution system;

f. provide adequate anti-siphon devices for all fluoride feed lines.

3.7.4 Protective Equipment - Suitable protective equipment should be provided. See bibliographical reference III-250.

3.7.5 Dust Control Equipment - Suitable equipment should be provided for wet-mopping and hosing dust that might accumulate in the plant.

3.7.6 Testing Equipment - Equipment should be provided for measuring the quantity of fluoride in the water. Such equipment should be subject to the approval of the State.

3.7.7 Defluoridation - Processes and equipment for removal of excess fluoride should be submitted to the State for approval.

3.8.0 Stabilization(III-20)

Water that is unstable due either to natural causes or to treatment given the water should be stabilized. Water may be unstable due to low pH, high pH, or excessive dissolved oxygen. Corrosion may also be caused by galvanic or biochemical action.

3.8.1 Carbon Dioxide Addition

a. Recarbonation chamber design should provide

1. detention for three to ten minutes;

2. depth about 2.5 meters (8 feet);

3. reaction tank with detention of twenty minutes.

b. Adquate precautions should be taken to prevent the possibility of carbon monoxide entering plant from recarbonation and reaction chamber.

c. Capacity$^{(I-60,Ks.)}$

Equipment for recarbonation of lime softened water shall produce not less than 60 Kg/million liters (500 lbs/million gallons) of carbon dioxide at maximum design rate. If the gas contains 10 percent carbon dioxide the capacity of the blower or compressor should be at least 3.7 L/sec per million liters (30 cfm per million gallons). Plants using carbon dioxide sources containing less than 10 percent CO_2 must increase compressor capacity proportionally. Adquate ventilation is necessary for cooling of recarbonation equipment rooms.

d. Application - Single stage recarbonation immediately ahead of filtration is recommended only for waters having a pH of less than 9.5. For waters having pH greater than 9.5 during treatment, two-stage recarbonation with intermediate settling may be required.

3.8.2 Sulphuric Acid

a. Feed equipment should conform to Section IV.

b. Adequate precautions should be taken for safety. See Section VIII.

3.8.3 Polyphosphates

Applicable for sequestering calcium in lime softening.

a. Feed equipment shall conform to Section IV.

b. Phosphate chemicals should be food grade.

c. Stock phosphate solution should be kept covered and disinfected by carrying approximately 10 mg/l chlorine residual.

d. Satisfactory chlorine residuals should be maintained in distribution system when phosphates are used.

3.8.4 "Split Treatment" - Under some conditions, a lime-soda water treatment plant can be designed using "split treatment" in which raw water is blended with lime treated water to partially stabilize the water. Treatment plants designed to utilize "split treatment" should also contain facilities for further stabilization by other methods.

3.8.5 Alkali Feed - Unstable water created by ion exchange process should be stabilized by an alkali feed. An alkali feeder should be provided for all ion exchange water softening plants except when exempted by the State.

3.8.6 Carbon Dioxide Reduction by Aeration - The carbon dioxide content of an agressive water may be reduced by aeration. Aeration devices should conform to 3.5.

3.8.7 Other Treatment - Other treatment for controlling corrosive waters by the use of sodium silicate bicarbonate may be used where necessary. Any proprietary compound should receive the specific approval of the State before use. Chemical feeders shall be as required in Section IV.

3.8.8 Water Unstable Due to Biochemical Action in Distribution System - Unstable water resulting from the bacterial decomposition of organic matter in water (especially in dead end mains), the biochemical action within tubercles and the reduction of sulfates to sulphides should be prevented by the maintenance of a chlorine residual throughout the distribution system.

3.8.9 Control - Laboratory equipment shall be provided for determining the effectiveness of stabilization treatment.

3.9.0 Taste and Odor Control(III-20)

3.9.1 Chlorination - Chlorination can be used for the removal of some objectionable odors. Adequate contact time must be provided to complete the chemical reactions involved.

Chlorine Dioxide - Chlorine dioxide is a possible treatment for tastes caused by industrial wastes, such as phenols; however, chlorine dioxide can be used in the treatment of any taste or odor that is treatable by an oxidizing compound. Provision shall be made for proper storing and handling sodium chlorite, so as to eliminate any danger of explosion. See Part 4.

When chlorine or chlorine compounds are used to oxidize organic matter in water, consideration must be given to preventing potentially harmful chloro-organic compounds from reaching consumers by their adsorption on activated carbon or their removal by coagulation and filtration.

3.9.2 Powdered Activated Carbon

a. Powdered activated carbon may be added prior to coagulation to provide maximum time, although facilities to allow the addition at several points is preferred, but not near the point of chlorine application. Addition directly ahead of mixed-media filters may also be considered.

b. The carbon can be added as a pre-mixed slurry or by means of a dry-feed machine as long as the carbon is properly "wetted".

c. Agitation is necessary to keep the carbon from depositing in the mixing chamber.

d. Provision should be made for adequate dust control.

e. The required dosage of carbon in a water treatment plant depends upon the tastes and/or odors involved, but provisions should be made for adding 0 to 40 mg/l.

3.9.3 Granular Activated Carbon Adsorption Units - Rates of flow in granular activated carbon units should be consistent with the type and intensity of the problem. The rate used should be supported by the results of pilot plant studies. In design, attention should be given to the use of the granular activated carbon units to adsorb as many organics as possible to reduce health hazards believed to be associated with chlorinated organic compounds, both of natural and man-related sources.

3.9.4 Copper Sulphate and Other Copper Compounds - Continuous or periodic treatment of water with copper compounds to kill algae or other growths should be controlled to prevent copper in excess of 1.0 mg/l as copper (II-71) in the plant effluent or distribution system. Care should be taken to obtain a uniform distribution and to avoid local high concentrations.

3.9.5 Potassium Permanganate - Application of potassium permanganate may be considered providing the treatment should be so designed that the products of the reaction are not present in the finished water.

3.9.6 Other Methods - The decision to use any other methods of taste and odor control should be made only after careful laboratory tests and on consultation with the State.

3.9.7 Flexibility - Plants treating water that is known to have taste and odor problems should be provided with equipment that makes several of the control processes available so that the operator will have flexibility in operation.

(Also see Section 3.13, Organics Removal by Granular Carbon

Adsorption.)

3.10.0 Microscreening(III-20)

A microscreen is a mechanical device capable of removing suspended matter from the water by straining. It may be used to reduce plankton and other nuisance organisms and organic loadings on filter systems. It should not be used in place of:

a. filtration, when filtration is necessary to provide a satisfactory water,

b. coagulation in preparation of water for filtration.

3.10.1 Design

a. should give due consideration to

1. nature of suspended matter to be removed,

2. corrosiveness of the water,

3. effect of disinfection, when required as pretreatment.

b. should provide

1. durable, corrosion-resistant screen,

2. by-pass arrangements,

3. protection against back-siphonage when potable water is used for washing,

4. proper disposal of wash waters.

3.11.0 Waste Disposal(III-20)

Provisions should be made for proper disposal of water treatment plant waste such as sanitary, laboratory, clarification, softening, and ion sludges, filter backwash, and brines. Discharges are governed by State Water Pollution Control Agency requirements and Federal Regulations. See Section 1.6, Disposal of Plant Wastes for coverage of this subject.

3.12.0 Salt Removal(III-274)

There are three general methods for removing dissolved salts from water and reducing the content of total dissolved solids (TDS). They are iron exchange, reverse osmosis, and electrodialysis.

3.12.1 Ion Exchange - The ion exchange process has been used for many years in the U.S. for the softening of public water supplies and there are several large plants which have operated successfully for many years. There is also a small selective ion exchange plant which removes nitrate from a ground water supply. However, ion exchange has been applied to only one public water supply for purposes of reducing the total mineral content. This 2 million liters (0.5 mg) per day moving bed ion exchange plant treats a potable supply which has been contaminated by acid mine drainage. It serves the city of Burgettstown, Pennsylvania.

It is possible to use many combinations of various cation and anion exchange resins to demineralize water. Fixed bed and moving bed systems are suitable. The units may be either upflow or downflow, using automatic or manual regeneration. Suitable disposal should be provided for regenerate wastes and rinse water. Pilot plant tests using water to be treated may be necessary to check the suitability of ion exchange systems for the particular waste to be desalted. Applicability of the process chosen shall be demonstrated.

3.12.2 Reverse Osmosis - This desalting process has been intensively developed in the last few years. The first municipal plant utilizing reverse osmosis was constructed at Greenfield, Iowa in 1971 to a capacity of 568,000 Lpd (150,000 gpd). A 1,325,000 Lpd (350,000 gpd) plant serves the Ocean Reef Club community on the northern tip of Key Largo, Florida. The largest reverse osmosis (RO) plant in the world is located at Kashima, Japan. It is being expanded to a capacity of 5.3 million Lpd (1.4 mgd).

There are several types and configurations of RO equipment which are suitable for use in demineralizing public water supplies. Pilot plant tests may be desirable to check the suitability of equipment for the particular water to be treated. Applicability of the process should be demonstrated, to the satisfaction of the State.

3.12.3 Electrodialysis - This was the first process to be fully developed for desalting brackish public water supplies. Currently, five plants in the U.S. desalt brackish waters by the electrodialysis for producing potable water. The electrodialysis plant with the longest history of operation is located at Buckeye, Arizona. It was built in 1962 and has a capacity of 2.3 million Lpd (650,000 gpd). The largest plant of this type is now under construction at Foss Reservoir in Oklahoma. It will have a capacity of 11.4 million Lpd (3 mgd).

Again the applicability of the process and equipment chosen shall be demonstrated to the State for the particular water to be treated.

3.13.0 Organics Removal by Granular Carbon Adsorption(III-14)

There is an increasing awareness of the need to remove organic chemicals, both natural and synthetic, from drinking water supplies, not only to remove more completely taste and odor for esthetic reasons, but also for protection of public health through reduction of the potential to form carcinogenic compounds by reaction between chlorine and various organic chemicals. Granular carbon adsorption is a leading candidate process for these purposes.

3.13.1 Adsorption of Organics on Granular Activated Carbon - This process is dependent on bringing the water to be treated in contact with granular activated carbon by upflow or downflow through an expanded or packed bed. Removals of organics obtained depend upon the character of the water and the materials to be adsorbed as well as the character of the activated carbon. The pH of the water should be less than 9.0, preferably less than 7.0 for best results. The turbidity of the applied water should be low when packed beds are used. A turbidity of 2JU is acceptable, but less than 0.5 JU is preferred. Within the normal range of water temperature, 0 to 200C., a rise in temperature favors better adsorption.

3.13.2 Granular Activated Carbon Specifications - To permit handling and to resist abrasion, the granular carbon should be hard and dense and be manufactured from coal. Its properties should be as follows:

Total surface area, M^2/g	850 - 1,500
Bulk density, Kg/Cu.M	417
Bulk density, (lbs/cf)	26
Particle density, wetted in water, g/cc	1.3 - 1.4
Effective size, mm	0.8 - 0.9
Uniformity Coefficient	1.9 or less
Mean particle diameter, mm	1.5 - 1.7
Iodine number, minimum	850
Abrasion number, minimum	70
Ash, maximum percent	8
Moisture, maximum percent	2

For downflow beds or packed upflow beds, the nominal size distribution should be 8 x 30 mesh with not more than 1 percent passing a 30 mesh U.S. Standard Sieve and not more than 3 percent retained on an 8 mesh sieve. Mean particle diameter should be 1.6 mm.

For expanded upflow beds, the nominal size distribution can be 8 x 30 mesh or optionally may be 14 x 40 mesh. Not more than 1 percent should pass a 40 mesh sieve and not more than 3 percent should be retained on a 14 mesh sieve. Mean particle diameter shall be 0.9 mm.

Other carbons may be approved at the discretion of the reviewing authority. Reference should be made to the AWWA Standard for Granular Activated Carbon, AWWA B604-74 (First Edition), J.AWWA, p. 672, November, 1974.

3.13.3 Contact Time - The carbon beds or columns should provide sufficient time of contact between carbon and the water being treated at design flow for the desired degree of organic removals. Within the range of 80 to 400 Lpm/Sq.M (2 to 10 gpm/sf) surface loading rates are not critical to organic removals obtained. Bed depths vary from 0.76 to 7.6 meters (2.5 to 25 feet) or more. In general, contact times may vary from 5 to 45 minutes or more depending upon the desired degree of removal and the organics to be adsorbed. Pilot carbon column tests are recommended to obtain the necessary design criteria for time of contact. The procedure for performing such tests is given on pages 140 to 145 of " Advanced Wastewater Treatment", by Culp and Culp, Van Nostrand Reinhold Co., New York, 1971.

The pilot test results make it possible to:

1. Determine the minimum contact time required to produce the desired quality of carbon column effluent.

2. Compare the performance of two or more carbons under the same dynamic flow conditions.

3. Check head loss at various flow rates and through different bed depths.

4. Check the backwash flow rate necessary to expand the bed for cleaning purposes.

5. Establish the carbon dosage required in terms of Kg/Cu.M (lbs. per million gallons), which is necessary to determine the capacity of the carbon regeneration furnace and auxiliaries.

6. Determine pretreatment requirements.

3.13.4 Carbon Bed or Column Design - For taste and odor control, it has been common practice to convert existing rapid sand filter boxes to shallow downflow combination filtration-contactor units. Such beds have proved to be quite satisfactory for this purpose, but it is very likely that much longer contact times will be required to obtain organic removals of the order necessary to restrict production of chloro-organic compounds which may be hazardous to health. The longer contact times needed for this purpose probably will require specially designed carbon contact vessels. The general types of carbon contactors are:

1. Upflow, countercurrent, either packed or expanded. A single unit is acceptable. If more than one unit is used, they would operate in parallel.

2. Downflow, two or more beds in parallel.

3. Two or more sets of two series downflow beds.

Contactors may be designed as open gravity units, or pressure beds. They may be constructed of concrete, steel, or fiberglass reinforced plastic. Steel vessels should be protected against corrosion by coaltar epoxy coating, rubber or glass lining, or other means.

All carbon beds or columns should be equipped with provision for flow reversal. Granular carbon beds used only for organic removal and with turbidity of applied water less than 2.5 JU (whether upflow or downflow) require only about 10 percent expansion for cleaning (reducing head loss through the bed). Combination downflow filter-contactors require backwashing facilities to provide up to 50 percent bed expansion and should meet the same backwash criteria as rapid filters. See Section 3.2, Filtration.

Inlet and outlet screens should be 304 or 316 stainless steel or other suitable materials. A screen slot size 0.05 mm (0.020 inches) will retain 8 x 30 mesh carbon and a screen slot size of 0.036 mm (0.014 inches) will retain 12 x 40 mesh carbon.

Carbon beds and columns also require means for removing spent carbon and introducing makeup or regenerated carbon. Forty-five degrees conical or pyramidal top and bottoms facilitate uniform distribution of carbon being introduced and provide for easy removal of spent carbon.

Pressure contactors should be equipped with air-vacuum release valves fitted with a stainless steel screen, slot size 0.036 mm (0.14 inches), to prevent plugging with carbon.

Carbon should be conveyed to and from the carbon bed or column in water slurry. Carbon slurries can be transported by use of diaphragm slurry pumps, water-jet eductors, a low-speed, rubber-lined, recessed impeller, centrifugal pumps.

3.13.5 Carbon Regeneration - Spent or exhausted granular carbon may be thermally regenerated in a low-oxygen steam atmosphere at temperatures above 660°C (1,500°F) in such units as a multiple hearth furnace or an all-electric, infra-red, moving belt furnace. Such furnaces shall be equipped with exhaust gas afterburners and scrubbers (Venturi or jet-impingement type) for air pollution control. Consideration should be given to economic feasibility (see III-14).

The required furnace capacity can be determined by multiplying the carbon dosage in terms of Kg/million L (pounds per million gallons) by the daily flow rate in Lpd (mgd), with an allowance of 40 percent for furnace downtime.

Multiple hearth furnaces used for regenerating carbon should provide a hearth, one of about 1 Sq.M for 195Kg (one square foot per 40 pounds) of carbon, to be regenerated per day.

The regeneration furnace should be designed so that hearth temperatures, spent carbon feed rate, rabble arm speed, and steam addition can be controlled.

The carbon regeneration process is controlled by the apparent density (AD) and iodine number of the carbon. Virgin carbon would have an AD of about 0.48 and an iodine number of about 900. Spent carbon would have an AD of about 0.52 to 0.59 and an iodine number of 550 to 850. Regeneration should restore the AD and iodine number to near those for virgin carbon.

Carbon losses during each regeneration cycle should be less than 10 percent, averaging in the range of 5 to 8 percent.

3.14.0 Activated Carbon for Dechlorination

Carbon has been used for many years to dechlorinate waters. The life of granular carbon in properly designed dechlorination service is extremely long.

The basic design parameters for an activated carbon dechlorinator are: (1) chemical state of the free chlorine, (2) pH, (3) inlet chlorine concentration, (4) flow rate through the carbon bed, (5) particle size of the carbon, (6) type of carbon, (7) mode of operation (continuous or interrupted), and (8) impurities present.

Because of the number of variables and the wide ranges of values involved, the designer should submit his proposal for a carbon dechlorination system to the State for approval.

3.1.0 Clarification

It is advisable to provide duplicate units for flocculation and sedimentation to permit continued operation of the water treatment plant when units are taken out of service for maintenance or repair. Otherwise, with only a single flocculation or settling basin available, long-term shutdown for painting equipment or to repair a flocculator assembly, sludge collection equipment, or a sludge pump could seriously disrupt water service to consumers.

Raw waters which are high in turbidity, color, dissolved solids, bacteria, or other undesirable constituents may need multiple-stage rather than single stage clarification in order to produce acceptable results. When this is the case, based on the judgement of the State, multiple-stage clarification may be required. Examples of multi-stage treatment are: (1) presedimentation followed by chemical application, rapid mixing, flocculation, and settling, or (2) presedimentation; primary rapid mixing, flocculation and settling, followed by secondary rapid mixing, flocculation and settling.

3.1.1 Presedimentation

The purpose of presedimentation treatment is to reduce the load of sand, silt, turbidity, bacteria, or other substances which is applied to subsequent treatment processes, so that they may function more efficiently. When the raw water has exceptionally high concentrations of the substances mentioned, good removals are often obtained by plain settling and without the use of chemicals. In other cases it may be advantageous to add ozone, chlorine, or other disinfectant to reduce the bacterial load, or to add a polymer or alum, lime, activated silica, or other coagulant in the pretreatment process.

Since the load of silt and sand to be removed from presedimentation basins is usually quite high, heavy duty sludge collection equipment should be used so that it will give good service.

Because the particles to be removed are more readily settleable than chemical flocs, the detention time may be shorter and the surface overflow and weir rates may be greater for presedimentation basins than for primary or secondary settling basins, as reflected in the Summary of Standards at the beginning of this Section.

3.1.2 Mixing

In discussing mixing and flocculation, it is important to distinguish between coagulation and flocculation. Coagulation is the chemical reaction between the applied chemicals and the colloidal particles in the water. This reaction is almost instantaneous. Intense mixing is necessary at the point of chemical application in order to obtain uniform chemical distribution and exposure of the colloids in the water to the coagulant before the coagulation reaction is completed. This is the purpose of the rapid mix.

The term flocculation refers to the agglomeration of small coagulated particles to form larger floc particles which are susceptible to removal by settling or filtration. This process is partly a physical one which is dependent on the number of opportunities for contact between coagulated particles as well as chemical bridging action. It is a much slower process than coagulation and is more time dependent.

The process of coagulation and flocculation are influenced by variable physical and chemical forces including particle size, charge, and concentration, exchange capacity, pH, water temperature, electrolyte concentration, and a host of other factors. The basic principles of design were published by Camp* in 1955. They are based on the rate of power input to the water as measured by the velocity gradient. Multiplying the velocity gradient (G) by the detention time (T) in the basin gives another (dimensionless) parameter, GT, which is used in flocculation basin design. However, most of the design standards are emperical ones based on experience from operating treatment plants.

Mechanical rapid mixer design practice is to provide velocity gradients of G= 300 meters per sec/meter (300 fps/foot) or more. Power requirements vary from 0.07 to 0.27 metric HP/million lpd (0.25 to 1.0 HP/mgd).

3.1.3 Flocculation (Slow Mixing) Basins, Primary or Secondary

After rapid mixing of the coagulant and the water to be treated, a period of prolonged agitation is provided for flocculation at values of GT in the range of 30,000 to 150,000. Flocculator agitators usually are designed to operate at speeds of 0.2 Mpm (0.6 fpm). Flocculation basin detention times vary from 20 to 60 minutes. Velocity gradients (G) range from 5 to 100 meters/sec/meter (5 to 100 fps/f). Ordinarily plant trials or laboratory tests are needed to establish G and T.

When water is difficult to flocculate and the floc is weak, velocity gradients in the low range should be used. When water flocculates readily and floc is strong, high velocity gradients are desirable.

Once formed, floc may be broken up at points of increased agitation such as changes in direction of flow in pipes or channels or drop over a weir. Often flocculation basins are built immediately adjacent to or integral with settling basins to avoid the need for connecting pipes or flumes. Floc strength may be increased by use of a polymer or activated silica. The best point for application of activated silica varies and should be determined by trial and error.

---

*Camp, T.R., "Flocculation and Flocculation Basins", Trans. ASCE, p. 1, 1955.

Tapered flocculation at decreasing G values may be advantageous in some circumstances. Mechanical flocculators should be equipped with variable speed drives to be able to match G values with changing flow rates. Because baffled flocculation basins do not have the adaptability to vary G with flow changes, they have fallen into disfavor.

3.1.4 Sedimentation

The usual practice is to follow flocculation with sedimentation in order to reduce the load of solids applied to filters. A major portion of the solids can be removed from the water by gravity settling action and decanting of the clarified water over a basin outlet weir or through outlet orifices. However, with the recent development of coarse-to-fine filters, through the use of mixed media or dual-media, filters can handle much heavier loads of applied suspended solids at reasonable head losses than was possible in the past using single media, fine-to-coarse filters. This makes it possible to consider direct filtration (without settling following flocculation) in an increasing number of situations, and this is influencing current design practice to a great extent. One advantage of direct filtration is that chemical treatment of the water can be tailored initially (without adjustment in the filter influent) to the optimum filtrability rather than to settleability (with subsequent adjustment to filtrability by addition of a polymer or other filter aid to the water applied to filters).

Despite the use of sedimentation for centuries and all the attempts at mathematical formulation, good settling basin design is based more on experience and judgment than on the results of calculations. Recently shallow-depth sedimentation has been perfected through the use of tubes or plates. The performance of settling tube and plate devices corresponds more closely to results predicted by mathematical formulation than do conventional settling basins. The use of settling tube clarifiers also greatly reduces space requirements and detention times.

Inlet and outlet arrangements and the means for sludge removal are very important to good settling basin design and performance.

Removals of different substances from water by plain sedimentation or by chemical flocculation and sedimentation vary quite widely depending upon the raw water quality, the chemicals used, the equipment available, and the skill of operation. This makes it difficult to generalize, but some idea of the range of capability of these processes can be gained from the examples which follow.

For presedimentation only, the efficiency of treatment as measured by coliform reduction is (1) 90 percent or more for heavy coliform loadings (20,000 to 60,000 MPN per 100 ml) and long presedimentation periods (5 to 10 days), and (2) about 20 percent for light coliform loadings (5,000 to 20,000 MPN per 100 ml) and shorter detention times (3 to 7 hours). The relatively long storage periods provided by presedimentation are also valuable in providing time for the natural die-away of virus which are in an unfriendly environment (III-179).

In plants with predisinfection, flocculation, and sedimentation, the reduction in coliform organisms through these three processes is excellent. In a study* of 19 treatment plants, representing 432 plant months examined, there were 36 months during which the percentage of coliform positive portions exceeded 2 percent of those examined, and 3 months during which they exceeded 10 percent of those examined. Raw water coliform densities during the tests ranged from 5,000 to 490,000 monthly average MPN per 100 ml. Predisinfection, coagulation, and sedimentation are commonly used as pretreatment to filtration. Alone, they should not be considered adequate treatment for raw waters subject to any appreciable contamination.

In the past the goal for removal of turbidity by treatment prior to filtration has been to reduce the turbidity to about 1 to 5 JU with 10 JU as a maximum. This still applies to single media, fine-to-coarse filters. Mixed media and dual media beds can be operated with applied turbidities as high as 50 to 200 JU.

Since the general practice is to combine flocculation and clarification with filtration, the discussion of removal efficiencies of other substances of interest in meeting the Federal Drinking Water Standards is deferred to later Sections of this Manual. Even though flocculation and clarification may be the principal means for removal of many of the substances of interest, the presentation is made as combined or related to other processes involved in the desired overall removal.

3.1.5 Solids Contact Units

These units seek to combine coagulation, flocculation, and sedimentation in a single basin. Also, settled sludge may be recirculated internally or externally. The chief advantage of the solids contact units is the easy internal recirculation and suspension of precipitated solids, particularly the recirculation of calcium carbonate sludge in treatment of well waters. The chemical and physical reactions of lime-soda softening are accelerated by contact with previously precipitated calcium carbonate. In the treatment of surface waters containing turbidity or organic matter, internal sludge recirculation may be a disadvantage rather than an advantage, as it may be desirable to purge the system of organics as quickly and completely as possible to avoid production of tastes and odors and to avoid interference with coagulation and settling by organics. When upflow units are used for clarifiers without softening, it is advantageous to separate the mixing, flocculation, and settling processes. This allows observation of changes taking place in each of the three individual processes in response to changes in plant flow, raw water composition, or chemical dosages. Cause and effect are more easily related and plant control is improved. For these reasons, special approval of the State must be obtained for use of solids contact basins as clarifiers without softening. The best application of solids contact basins is to the softening of well waters of constant quality at a uniform basin throughput rate.

---

*Walton, G., "Effectiveness of Water Treatment Processes as Measured by Coliform Reduction", U.S.P.H.S., Cincinatti, Ohio, 1956.

3.1.6 Settling Tube Clarifiers

Settling tube clarifiers are the practical embodiment of shallow depth sedimentation theory and principles. The original research and development was conducted by equipment manufacturers, and design criteria are being refined by data being obtained from a rapidly increasing number of full plant scale installations in municipal and industrial water treatment plants. The Summary of Standards in this Manual reflects the most recent information available for proper design or selection of settling tube clarifiers. These criteria may well be subject to change, as refinements in design improve settling by means of these devices to more closely approach ideal settling basin characteristics. Application of this theory offers tremendous potential for improving the efficiency and economy of sedimentation facilities.

3.2.0 Filtration

The filtration process is the heart of water treatment plant operations. It is highly efficient and reliable and serves many purposes. Water filtration is a physical-chemical process for separating suspended and colloidal impurities from water by passage through a bed of granular material.

The three general types of filters currently in use in public water systems are rapid rate gravity filters, rapid rate pressure filters, and slow rate gravity filters. These are the three filter types covered by the Standards in this Manual.

All surface water supplies should be filtered. Some well waters meet water quality standards and goals without treatment, while other well waters require only disinfection. On the other hand, many well waters require treatment for removal of iron, manganese, hardness, color, odor, turbidity, hydrogen sulfide, bacteria, virus, or other undesirable impurities. In these cases, filtration is ordinarily a part of the overall purification process.

Where there is no full plant operating experience with a particular water to be treated, or where the records are not adequate to determine the best treatment processes to be used, pilot plant studies are a valuable aid to producing the most efficient and economical scheme of treatment. They are highly recommended under these conditions. Pilot studies can be used to determine the kind and extent of pretreatment which may be required ahead of filtration. Only a filter itself can reveal through its operation the characteristic of floc particles and filter media that bear on removal efficiency and length of filter runs. While backwash rates are well-standardized, it is good to check them through pilot plant operation on a particular water to be treated. In conducting pilot plant tests, the necessity to operate under all raw water conditions must not be overlooked. Unless the pilot plant is operated under the most severe conditions, the full scale plant may be underdesigned and ill-equipped to produce the desired water quality at all times, as is necessary.

3.2.1 Rapid Gravity Filters

3.2.1.1 Pretreatment

In water treatment, the general practice is to reduce the turbidity of water to 10 JU before application to rapid sand filters. However, mixed-media filters can and are handling applied turbidities up to 50 JU on a continuous basis, and will tolerate occasional turbidity peaks of 200 JU. Provisions should be made in plant design to disinfect filter influent as an aid to maintaining clean filters. Provisions should also be made for application of a filter aid such as alum, activated silica, or a polymer ahead of the filters so that the water can be adjusted to optimum filtrability.

3.2.1.2 Number

In medium and large plants, the minimum number of filter units is usually 4. In small plants it may be 2. The maximum size of a single filter unit is limited by the rate at which backwash water must be supplied, difficulties in providing uniform distribution of backwash water over large areas, reduction in filter plant capacity with one unit out of service for backwashing, and structural considerations. The largest filter units in service are about 186 Sq.M (2100 ft^2) in area.

Units larger than about 93 Sq.M (1000 ft^2) may be built with a central gullet so that each half of the filter can be backwashed separately.

To filter a given quantity of water, the capital cost of piping, valves, controls, and filter structures is usually less for a minimum number of large filter units as compared to a greater number of smaller units. In expanding existing plants, it may be better not to increase the size of filter units but rather to match the existing size in order to avoid the need to increase the capacity of wash water supply and disposal facilities.

3.2.1.3 Rate of Filtration

The nominal and maximum filter throughput rates are based on experience in the operation and observation of water treatment plants. In the rates established by the Standards, the intent is to provide some factor of safety in these rates.

3.2.1.4 Structural Details and Hydraulics

For gravity filter structures, either concrete or steel may be used. Concrete boxes may be either rectangular or circular. Steel tanks are usually circular. For small tanks and pressure filters, steel is usually preferred. For large filters, concrete is the choice.

There are a number of special structural considerations involved in reinforced concrete filter boxes which deserve the attention of designers. They must carry not only wind, dead and live loads, but hydrostatic loads as well. To be watertight, walls should be not less than 23 cm (9 inches) thick. Walls must often be designed to withstand water pressure from either of two directions, and to resist sliding and overturning. Slabs also may be subject to hydrostatic uplift as well as gravity loads. Shear and watertightness require special attention particularly at keyways at the base of walls. The deflection at the top of cantilever walls and sliding at the base are common sources of trouble in water bearing concrete structures. The concrete should be impervious to minimize the deleterious effects of freezing and thawing, and ample cover should be provided for steel reinforcement. The difference in expansion between water-cooled walls and floors and exposed slabs and roofs must be considered. The location and design of construction and expansion joints should be shown on the plans by the engineer and not left to the judgment of the field inspector or contractor.

One filter arrangement is to place filters side by side in 2 rows on opposite sides of a central pipe gallery. One end of the rows of filters should be unobstructed to allow construction of additional units in future expansion.

The use of common walls between filtered and unfiltered water should be avoided in order to eliminate the possibility of contamination of the finished water. For the same reason, it is better not to construct clearwell storage beneath the pipe gallery floor.

3.2.1.5 Washwater Troughs

To equalize the head on the underdrainage system during backwashing of the filter, and thus to aid in uniform distribution of the wash water, a system of weirs and troughs is ordinarily used at the top of the filter to collect the backwash water after it emerges from the sand and to conduct it to the wash water gullet or drain. The bottom of the trough should be above the top of the expanded sand to prevent possible loss of sand during backwashing. The clear horizontal distance between troughs is usually 1.5 to 2.1 M (5 to 7 feet). If the filter troughs are to properly serve their purpose, after placement their weir edges must be honed to an absolutely smooth and perfectly level edge as determined by matching the finished edges of all troughs in a single filter to a still water surface at the desired overflow elevation.

3.2.1.6 Filter Material

The Standards for filter materials reflect the best current practice in design of fine-to-coarse, single-media filters of sand or coal, and coarse-to-fine filters of coal and sand, activated carbon and sand, or coal, sand and garnet or ilmenite. Specifications are also given for gravel supporting beds for fine filter media.

3.2.1.8 Filter Bottoms and Strainer Systems

Filter underdrains have a two-fold purpose. The most important is to provide uniform distribution of backwash water without disturbing or upsetting the filter media above. The other is to collect the filtered water uniformly over the area of the bed. Ideally, the filter underdrain system would also serve as a direct support for the fine media. There is one type of underdrain (porous plates) which can do this under certain special conditions as will be described later. However, the three most widely used underdrain systems all require an intermediate supporting bed of gravel which should be topped with a layer of coarse garnet or ilmenite to prevent upsets of the gravel layer. All of the systems accomplish the uniform distribution of wash water by introducing a controlling loss of head, usually about 1 to 4.5 M (3 to 15 feet) in the orifices of the underdrain system. The orifice loss must exceed the sum of the minor (manifold and lateral) head losses in the underdrain to provide good backwash flow distribution.

Several underdrain systems have been developed with the goal of eliminating the need for the gravel support bed. These systems employ strainer-like nozzles or porous plates. Plastic or steel nozzles of various shapes are available from several manufacturers.

Porous plates made of aluminum oxide, are also available to eliminate the need for the gravel layer. The aluminum oxide plates are usually mounted on steel or concrete frames which support the plate on at least two edges, or by studs projecting from the filter floor fastened to the corners of the plates. Mastic or caulking compounds are used to seal the joints. The disadvantages of the aluminum oxide plates are that they are brittle and easily broken during installation; also, the sealing of joints between plates may be difficult and the plates can become plugged from either side. If plugged plates are not promptly cleaned, structural failure may occur due to decreasing differential pressures across the plates during backwash. They offer the advantages of good flow distribution and minimum filter height since the media can be placed directly on the plates. They may not be suitable for use in filtering water which deposits calcium carbonate due to plugging problems under this condition.

A decision to use a nozzle or porous plate underdrain system should be based on the personal satisfactory experience of the designer in similar applications. In general, currently available direct support systems have not yet proven to be as satisfactory as gravel support beds for fine media.

3.2.1.9 Surface Wash

Present practice in the U.S. leans heavily toward installation of surface wash on all new filters. Auxiliary scour or filter agitation better describe the function of this device, as it aids in cleaning much more than the filter surface. Rotary surface washers are the most common, but fixed jets are also used successfully. In the past, air scour and mechanical scour have not been used extensively in the United States, but recent developments in this area may change this in the future. Adequate surface wash improves filter cleaning and prevents mudball formation and filter cracking.

Surface wash piping is a direct cross connection between filtered and unfiltered water, so that the normal practice is to bring the surface wash header into the filter over the top of the filter box and to fit it with a vacuum breaker and a check valve at the high point to prevent back-siphonage. An alternate is to use settled water through a separate surface wash pump.

3.2.1.10 Appurtenances

Ordinarily filters are equipped with a means of controlling the rate of flow through each bed. By controlling either the influent or the effluent flow it is possible to divide the flow among the filters, to limit the maximum flow through any unit, and to prevent sudden flow surges. Rapid changes in rate of flow through a filter are undesirable because they literally shake the floc particles down through the bed and into the effluent.

The loss of head through a filter provides valuable information about the condition of the bed and its proper operation. An increase in the initial loss of head for successive runs over a period of time may indicate clogging of the underdrains or gravel, the need for auxiliary scour, or insufficient washing of the beds. The rate of head loss increase during a run yields considerable information concerning the efficiency both of pretreatment and filtration. Headloss equipment may be used in connection with control systems for automatic backwashing of filters as one means of initiating the backwash cycle when the headloss reaches some preset maximum value.

It is now common practice to use polymers as filtration aids. Polymers are high molecular weight, water soluble compounds which can be used as primary coagulants, settling aids, or filtration aids. They may be cationic, anionic, or nonionic in charge. Generally, the doses required as a filtration aid are less than 0.1 mg/l. Used as a filtration aid, polymer is added to increase the strength of the chemical floc and to control the depth of penetration of floc into the filter. For maximum effectiveness as a filtration aid, the polymer should be added directly to the filter influent.

Inexpensive, reliable turbidimeters are available to continuously monitor the quality of filter effluent. Should the turbidity exceed the desired level, a signal from the turbidimeter can be used to sound an alarm or to initiate the backwash program. Recording of the turbidimeter output provides a continuous record of filter performance.

A small pilot filter receiving raw water dosed with the treatment chemicals is often operated in parallel with the plant filters. The pilot filter directly measures the filtrability of the water under actual plant operating conditions. By fitting the pilot filter with a recording turbidimeter, chemical dosages can be adjusted to obtain the desired quality of filter effluent before water in the full scale plant reaches the filters.

3.2.1.11 Backwash

During the service cycle of filter operation particulate matter removed from the applied water accumulates on the surface of the grains of fine media and in the pore spaces between grains. With continued operation of a filter the materials removed from the water and stored within the bed reduce the porosity of the bed. This has two effects on filter operation; it increases the head loss through the filter and increases the shearing stresses on the accumulated floc. Eventually the total hydraulic head loss may approach or equal the head necessary to provide the desired flow rate through the filter, or there may be a leakage or breakthrough of floc particles into the filter effluent. Just prior to either of these potential occurrences, the filter should be removed from service for cleaning. As mentioned previously, in slow sand filters the arrangement of sand particles is fine-to-coarse in the direction of filtration (down), and most of the impurities removed from the water collect on the top surface of the bed and the bed can be cleaned by mechanically scraping the surface and removing about one half inch of sand and floc. In rapid sand filters, there is somewhat deeper penetration of particulates into the bed because of the coarser media used and the higher flow rates employed. However, most of the materials are stored in the top 20 cm (8 inches) of a rapid sand filter bed. In dual media and mixed-media beds, floc is stored throughout the bed depth to within a few inches of the bottom of the fine media. Rapid sand, dual-media, and mixed-media filters are cleaned by hydraulic backwashing (upflow) with potable water. Thorough cleaning of the bed makes it advisable in the case of single media filters and mandatory in the case of dual or mixed media filters to use auxiliary scour or surface wash devices before or during the backwash cycle. Backwash should provide a 20 to 50 percent expansion of the filter bed. The optimum rate of wash water application is a direct function of water temperature, as expansion of the bed varies inversely with viscosity of the wash water. The time required for complete washing varies from 3 - 15 min. Following the washing process, water should be filtered to waste until the turbidity drops to an acceptable value. Filter-to-waste outlets should be through an air gap-to-waste drain which may require from 2 - 20 minutes, depending on pretreatment and type of filter. Modern recording turbidimeters have shown that this operation is valuable in the production of a high-quality water. Operating the washed filter at a slow rate at the start of a filter run may accomplish the same purpose. A recording turbidimeter for continuous monitoring of the effluent from each individual filter unit is of great value in controlling this operation at the start of a run as well as in predicting or detecting filter breakthrough at the end of a run.

Filters can be seriously damaged by slugs of air introduced during filter backwashing. The supporting gravel can be overturned and mixed with the fine media, which requires removal and replacement of all media for proper repair. Air can be unintentionally introduced to the bottom of the filter in a number of ways. If a vertical pump is used for the backwash supply, air may collect in the vertical pump column between backwashings. The air can be eliminated without harm by starting the pump against a closed discharge valve and bleeding the air out from behind the valve through a pressure air release valve. The pressure air release valve must have sufficient capacity to discharge the accumulated air in a few seconds.

Also, air or dissolved oxygen, released from the water or standing and warming in the wash water supply piping, may accumulate at high points in the piping and be swept into the filter underdrains by the inrushing wash water. This can be avoided by placing a pressure air release valve at the high point in the line, and providing a 1.25 cm (½ inch) pressure water connection to the wash watter supply header to keep the line full of water and to expel the air.

The entry for wash water into the filter bottom must be designed to dissipate the velocity head of the wash water in such a manner that uniform distribution of wash water is obtained. Lack of attention to this important design factor has often led to difficult and expensive alterations and repairs to filters for correction.

Horizontal centrifugal pumps may be used to supply water from the treated water storage reservoir for filter backwashing provided they are located where positive suction head is available, or are provided with an adequate priming system. Otherwise, a vertical pump unit may be suspended in the clear-well. The pumps should be sized to supply at least 610 Lpm/Sq.M (15 gpm/ft^2) of filter area to be washed, and should be installed with an adequate pressure air release valve, a nonslam check valve, and a throttling valve in the discharge. Duplicate wash water supply pumps should be installed for standby service.

Wash water may also be supplied by gravity flow from a storage tank located above the top of the filter boxes. Wash water supply tanks should have a minimum capacity equal to a 15 minute wash for 1 filter unit. The bottom of the tank must be high enough above the filter wash troughs to supply water at the rate required for backwashing as determined by a hydraulic analysis of the wash water system. This distance may be 3M (10 feet) but more often is 7.6 M (25 feet) or greater. Wash water tanks should be equipped with an overflow line, and a vent for release and admission of air above the high water level. Wash water tanks are often filled by means of a small electric driven pump equipped with a high-water level cutoff. They may also be filled from the high service pump discharge line through an altitude of float valve, but this is wasteful of power. Wash water tanks may be constructed of steel or concrete. Provisions should be made for shutdown of the tanks for maintenance and repair.

The wash water supply line should be equipped with provisions for accurately (within ± 5 percent) measuring and regulating the rate of wash water flow. The rate of flow indicator should be visible to the operator at the point at which the rate of flow is regulated.

The use of a high pressure source of filter backwash water through a pressure-reducing valve is not advised. Numerous failures of systems using pressure reducing valves have so thoroughly upset and mixed the supporting gravel and fine media that these materials had to be completely removed from the filter and replaced with new media.

3.2.2 Rapid Pressure Filters

The Rationale for gravity rapid filters also applies to rapid pressure filters.

3.2.3 Slow Rate Gravity Filters

The Standards for slow rate gravity filters are based on accepted practice in the past, when these filters were more commonly used. Few if any new slow filters are being built now.

3.2.4 Diatomaceous Earth Filtration

Diatomite filters consist of a layer of diatomaceous earth about 0.3 cm (1/8 inch) thick supported on a septum or filter element. The thin precoat layer of diatomaceous earth is subject to cracking and must be supplemented by a continuous body feed of diatomite. The problems inherent in maintaining a perfect film of diatomaceous earth between filtered and unfiltered water have restricted the use of diatomite filters for municipal purposes, except under certain favorable conditions.

The present status of the diatomite filter and its potential uses are well-summarized in the Third Edition (1971) of the Water Quality and Treatment as published by the AWWA, as quoted in the paragraphs which follow:

"The diatomite filter is an acceptable tool in the waterworks industry, but is only a step in the water-treatment process, the details of which must be predicated on the characteristics of the raw water and what must be done to condition the water prior to filtration. Present municipal experience relates principally to turbidity removal from surface waters, but experience is growing with installations designed for iron and manganese removal from groundwaters and with filtration of lime-soda ash-softened water and coagulated surface waters. Municipal experience with turbidity removal has been principally where the actual turbidity is relatively low and the bacteriological quality is good, thus little pretreatment is provided. There is no common agreement on the upper limits of turbidity that can be handled without pretreatment. There has been some extension of the use of diatomite filters in some of the areas (i.e. marginally, moderately, and grossly polluted surface waters) which have been of particular concern to regulatory public health personnel. No one should recommend diatomite filtration in the near future for filtration of a grossly or even moderately polluted supply. However, appropriate prior conditioning of such waters by one of several available means, including coagulation and settling or chemical treatment of the filter medium or water to improve water filtrability, will undoubtedly lead to wider application of diatomite filters. Currently, effective water conditioning coupled with filtration through carefully engineered filters, an appropriate filter aid body feed system, and with adequate disinfection should provide a substantial margin of safety for marginally polluted waters and even sometimes for moderately polluted waters."

"An advantage of a diatomite filtration plant for potable water is the lower first cost of such a plant. On waters containing low suspended solids, the diatomite filter installation cost should be somewhat lower than the cost of a conventional rapid-sand filtration plant. Diatomite filters will thus find application in potable water treatment under the following conditions:

1. In cases where the diatomite plant will be found to produce water at a lower total cost than any practical alternative.
2. In cases where financial capacity is tightly circumscribed, the lower first cost of a diatomite filter installation may be the major factor in the final choice of plant.
3. For emergency or standby service at locations experiencing large seasonal variations in water demand, the lower first cost of the diatomite filter may prove to be more economical."

3.2.5 Granular Carbon Filter Material

In Section 3.13 of this Manual, Organics Removal by Activated Carbon Adsorption, a detailed discussion is presented of carbon selection and the design of carbon systems tailored to optimizing organics removal. This Section deals with the combining of the activated carbon adsorption and filtration processes. This combination can be used in new plants, and it is easy to convert filters in existing plants to this arrangement.

Carbon for use in filter-contactors must be abrasion-resistant to withstand the frequent filter backwashing, it must be sized and graded to meet filtration requirements similar to those of coal in a dual-media bed, and it must have the capacity to adsorb organics from water.

3.3.0 Disinfection

Disinfection with ozone or chlorine is a vital process. It is the only means of assuring complete destruction of bacteria and virus. Pretreatment by various unit processes and combinations thereof may be necessary to prepare water for proper disinfection by ozonation or chlorination, but pretreatment cannot eliminate the need for such terminal disinfection. Disinfection of the community water supply is the last barrier to spread of waterborne disease.

In pretreatment it is advisable to remove as many natural and synthetic organic substances as possible from the water prior to the use of chlorine. Chlorine reacts with certain organic compounds to produce chloro-organic materials which may be carcinogenic to consumers. Chemical flocculation, oxidation, filtration, and particularly activated carbon adsorption may be useful in this regard. Activated carbon may also be used following chlorination of organics to adsorb some of the chloro-organic compounds formed although it is likely that not all such compounds would be removed completely. In view of the potential hazards from ingestion of chloro-organics, it may be advantageous to use ozone as the principal disinfectant, supplemented by only enough chlorine applied to the finished water to maintain minimum chlorine residuals in the distribution system, although it should be pointed out that ozone and ultra-violet radiation may also produce carcinogenic compounds in reaction with organics in water. The Standards for disinfection equipment are based on experience and current practice, and are similar to standards already in force in many states.

Because ozone cannot be stored, it must be generated on-site at the point of use. There is also a trend toward on-site generation of chlorine because of the recent development of reliable economical equipment for this purpose, because of frequent shortages in commercial supplies of chlorine, and because of the elimination of safety hazards in the transportation and handling of packaged chlorine.

In the design of chlorine application systems, the engineer must not overlook the importance of initial, violent, and complete mixing as there is a forty-fold spread between good and bad chlorine application and mixing systems so far as disinfection efficiency is concerned. Many full-scale chlorination facilities are inadequately designed with the chlorine applied directly to the chlorine contact basin, sometimes even without a diffuser. Flows in the contact basins are usually highly stratified, resulting in very little dispersion of the chlorine. Disinfection is one process for which any measurable short circuiting is completely ruinous to process efficiency. Attention to tank shape mixing and to proper baffling is critical.

Recent studies at the Sanitary Engineering Research Laboratory of the University of California evaluated the importance of rapid initial mixing in chlorination. The researchers believed that prolonged segregation of the chlorine from the bacteria results in poorer performance. The bactericidal compounds are formed by the reaction of chlorine with nitrogenous and carbonaceous matter to form chlorine complexes. The speed of these reactions varies; some are quite fast while others are relatively slow. They concluded that the residuals initially formed are apparently much more bactericidal than the compounds formed later. They concluded that rapid initial mixing allows these more lethal residuals to come in contact with the bacteria and act as killing agents.

It was also concluded that backmixing which occurs in a propeller-mixed tank may contribute to poorer disinfection. Reactions may take place between the more bactericidal residuals initially formed upon entering the reactor and the more complex residuals which form over a longer time. Thus, these simple and more bactericidal compounds may be destroyed before they can act.

Improved performance is provided by applying the chlorine to plug the flow reactors designed to provide rapid initial mixing. Where mechanically stirred mixers are necessary, the chlorine solution should be applied to the stream ahead of the mixer. The two process streams (chlorine solution and water) should not be applied directly and separately to the mechanical mixer.

The advantages of the high initial kill which rapid initial mixing provides are of significant importance. For example, existing plants which have CSTR (constant flow stirred tank) reactors for chlorination could be improved by installing a chlorine injection device in the pipe, if one exists, leading to the chlorine contact unit. Use of tubular reactors also provides a much better residence time distribution than a CSTR. This is particularly important in chlorination because the coliform kill is so strongly time dependent. Use of a CSTR allows short circuiting of fluid particles with short chlorine contact times and thus a very high concentration of coliform organisms.

3.4.0 Softening

Hard water is not suitable or desirable for many domestic, commercial, or industrial uses. Hard water comsumes soap, is not good for laundry, forms deposits on plumbing and heating systems, and is otherwise objectionable. It is economically sound to soften water at a central source of supply rather than in thousands of individual homes and businesses.

The Standards in this Manual are related to water softening in public water supply treatment plants by two methods: the lime-soda process and the cation exchange process. The choice between these two softening processes and the decision as to whether or not to soften at all must be based on the mineral qualities of the raw water supply, the desired finished water quality, the requirements for disposal of sludge or brine wastes, and costs.

Softened waters require stabilization treatment for control of corrosion in the distribution system and household plumbing to avoid high maintenance and replacement costs for pipe and fixtures. Equipment requirements in the Standards conform to current practice and existing state standards.

3.5.0 Aeration

The basic purpose of aeration is improvement of the physical and chemical characteristics of water for domestic, commercial, and industrial use. This may require either an increase or a decrease in the concentration of volatile substances in the water. The process of aeration involves intimate contact between water and air for the purpose of changing the content of volatile substances in the water.

Substances that may be decreased by aeration include: hydrogen sulfide, volatile organic compounds, carbon dioxide, and methane. Substances that may be added to the water by aeration include: oxygen (for oxidation of iron, manganese, hydrogen sulfide, and some organic matter) and carbon dioxide.

Because most substances causing taste and odor in water are not sufficiently volatile, aeration is not an efficient method for reduction or removal of taste and odor.

In the design of aerators, the aeration time and the ratio of surface area to the volume of water are important factors. There are two ways to control time and the area-volume ratio. One is to expose water films to the air and the other is to introduce small air bubbles into the water. The first method is known as the waterfall type, and the second as the diffused air type of aerator.

Aeration can be conducted under natural, induced, or forced draft or by pressure.

Design standards for aerators in this Manual are based on plant scale experience and state requirements, (III-20).

3.6.0 Iron and Manganese Control

There are a number of esthetic objections to iron and manganese in water supplies. In true solution these metals are colorless. Upon oxidation iron will impart a light yellow or reddish-brown color to the water, and manganese will produce a purple or black tinge. In combination oxidized iron and manganese in various combinations of concentration can produce a wide range of colors from yellow to orange to purple to black. These precipitates stain laundry, plumbing fixtures, and other materials which they contact. Iron and manganese accelerate growth of microorganisms in distribution systems, and, in dead end lines are often associated with hydrogen sulfide production because of the oxygen demand exerted. Accumulation of microbial growths can lead to reduced pipeline carrying capacity and the clogging of meters and valves. Sloughing off of the accumulations by increased flows often leads to consumer complaints of taste and odor. In concentrations of several mg/l, iron and manganese themselves will impart a medicinal, astringent, or metallic taste to water. In addition, the precipitation of these metals on the ion exchange resins of municipal or household water softeners is troublesome.

Iron and manganese are most commonly found in well waters from solution of these materials from rocks and minerals. Iron and manganese may also be present in surface water, particularly in water drawn from the bottom of deep lakes where iron and manganese may be dissolved under anaerobic conditions from bottom deposits or rocks and minerals on the lake bottom. Mixing or aeration of lakes to prevent oxygen and thermal stratification often will correct this condition. Iron and manganese may also be found in surface waters which receive acid industrial wastes or mine drainage.

Specific treatment processes employed in the control of iron and manganese deposition include: (1) oxidation, detention, and filtration, (2) removal in lime-soda softening, (3) continuous potassium permanganate regeneration, (4) ion exchange, and (5) sequestering with polyphosphates. As stipulated in the Standards, the exchange and sequestering processes are not applicable to waters containing more than 1.0 mg/l of iron and manganese.

Organic complexes of iron and manganese are much more difficult to remove from water than are the metallic ions, and potassium permanganate, ozone, chlorine, or chlorine dioxide may be useful in accelerating oxidation in the water treatment plant.

3.7.0 Fluoridation

Federal recommendations for fluoridation and the associated rationale and discussion are thoroughly and completely presented in a 94-page manual entitled "Fluoridation Engineering Manual" by Ervin Bellack, 1972. This manual is available from the U.S. Environmental Protection Agency (WH-450), Water Supply Division, Waterside Mall, Room E1101, Washington, D.C. 20460.

Fluoride chemicals should conform to the following AWWA Standards: sodium fluoride, B701-71; sodium silico fluoride, B702-71; hydrofluosilicic acid, B703-71.

3.8.0 Stabilization

Natural or treated waters may be unstable in one or both of two ways, they may be corrosive or scale forming (depositing). These characteristics of water can be measured by metal coupon tests (see AWWA "Quality Goals for Public Water", J.AWWA, p. 1317, 1968) or by calcium carbonate stability tests (marble test - see p. 330, Cox, Laboratory of Water Purification, Case-Sheppard-Mann Publ. Corp., New York, 1946).

The tendency of water to corrode metals or to deposit scale can be controlled or adjusted by: (1) carbon dioxide addition (recarbonation), (2) addition of sulfuric acid, (3) addition of polyphosphates, (4) split-treatment, (5) alkali feed, (6) aeration, or (7) other means.

If corrosion is not checked, costly replacement is inevitable. But long before this point is reached, the ill effects of corrosion are felt. Water quality deteriorates, carrying capacity decreases, pumping costs increase, and when the water is used for cooling more water must be used because heat transfer is retarded by deposits of corrosion products.

Protective measures against corrosion include: use of copper or copper alloy instead of galvanized iron in pipe manufacture; coating steel pipe with zinc; coating cast-iron pipe with coal tar; lining pipe with cement, and coating pipe in place after main cleaning.

Chemical control is a supplement to these measures and is not a substitute for them. Chemical control cannot overcome poor flow conditions, improper distribution system design, and defective pipe or coatings.

Polyphosphates are reported to be effective in reducing corrosion by domestic waters. They are effective only under certain conditions at certain concentrations and with certain waters. Polyphosphates are most effective at turbulent velocities and are not useful under stagnant or near stagnant conditions, such as in deadends or service lines. In hot water systems polyphosphates have a tendency to decompose and are not effective, particularly in hot water tanks.

Sodium silicate is a method for corrosion control particularly on waters with low hardness and alkalinity, and with a pH less than 8.4. treatment must be continuous.

Production of a water in the treatment plant which is stable or supersaturated with respect to calcium carbonate is by far the most widely applicable and successful method for prevention of red water and tuberculation of mains. The method has its limitations and is not a cure-all.

The Standards have been developed from current practices and existing State requirements.

3.9.0 Taste and Odor Control

The need for taste and odor control is principally to satisfy esthetic needs for a palatable water. However, there are associated health considerations. If water delivered to consumers from a public supply has an unpleasant taste or odor repeatedly, then some users will turn to other, less-safe, sources of drinking water. If the tastes or odors are attributable to the presence of chloro-organic compounds, there is a further relationship to public health, in that there is a need to remove the organics by activated carbon adsorption or other means prior to chlorination, or to remove the chloro-organics by subsequent carbon treatment.

In planning facilities for taste and odor control it is helpful to know what the potential sources of taste and odor may be, such as: algal growths, natural or synthetic organic materials, iron or manganese, sulfides, phenols, or industrial wastes. As already seen, iron, manganese, and sulfides can be removed by proper treatment. Many organic materials can be adsorbed by activated carbon adsorption. Some materials can be oxidized by chlorine, chlorine dioxide, or potassium permanganate. Some algal growths can be controlled by copper sulfate treatment at the source. It may be possible to exclude certain industrial wastes from entering the source of supply.

The Standards are applicable to utilization of these methods.

Further information on granular activated carbon adsorption of organics is given in Section 3.13 which follows.

3.10.0 Microscreening

Microscreening is a mechanical straining process which is particularly adapted to removal of algae from water. It is not comparable to chemical coagulation or granular bed filtration and should not be used in place of either of these processes.

Microstrainers are a tool to solve specialized problems, principally to remove troublesome algae ahead of sand filters. Since it is a surface filter or mechanical strainer, it is subject to many of the same limitations as are diatomite filters in its application to purification of water from contaminated sources for potable use.

The process of microstraining incorporates a specially woven stainless steel wire cloth mounted on the periphery of a revolving drum fitted with continuous backwashing arrangements. In operation, the drum is submerged in the flowing water to approximately two thirds of its depth. Raw water enters through the upstream open end of the drum and flows rapidly outwards through the microfabric, leaving behind its suspended solids content. These intercepted solids are carried upwards on the inside of the fabric under a row of washwater jets, from where they are flushed into a receiving hopper mounted on the hollow axle of the drum.

The wire cloths used in microstraining have apertures of 60, 35, and 23 μ with 60,000, 80,000 and 165,000 openings/in^2. The fabric may be woven so that the apertures are "three-dimensional" to provide high porosity, with durability and ease of backwashing. The flow capacity of a microstrainer depends on the rate of clogging of the fabric, drum speed, area of submergence, and head loss. These factors are combined in an exponential equation to obtain required plant size.

A portable testing kit has been developed to determine the filtration rate of any water source. Water under test is held in a reservoir and the time of discharge through a 1.2 cm (1/2 inch) diameter disc of micro fabric determines the "Filterability Index". Using this set, it is possible to specify the size of installation and operating efficiency for any project.

Microstraining has been used for removal of troublesome algae from lake waters upstream of conventional sand filters in several locations. At Denver, Colorado, an installation of twelve 3 meter (10 feet) diameter microstrainers, treats flows up to 379 million Lpd (100 mgd). Microstraining is the only filtration employed, the water being taken from a large upland reservoir where turbidity is low but plankton growths occur during spring and summer. Pilot plant tests made when this installation was being designed showed that the microstrainers removed more of the plankton organisms than sand filters.

A microstraining installation is operating in New York City, at outlet from the Jerome Park Reservoir. Two 3 meter (10 foot) diameter microstrainers are used to treat flows up to 53 million Lpd (14 mgd).

3.11.0 Waste Disposal (See Section 1.6)

3.12.0 Salt Removal

As water supply sources become subject to increasing use, reuse, and pollution, the removal of salts or reduction in total dissolved solids becomes a consideration in certain locations. Salt water conversion can also open up new sources of supply. In some areas the use of processes to remove excess mineral content is needed to meet Federal Drinking Water Standards.

The Standards in this Manual describe three methods for reducing the total dissolved solids content of water. Detailed design criteria are not set forth, only general requirements. Each proposal for a desalting plant will require individual consideration by the State. In each case, the applicability of the process and the anticipated performance and reliability of the equipment will need to be demonstrated to the satisfaction of the State.

3.13.0 Organics Removal by Granular Carbon Adsorption

3.13.1 Adsorption of Organics on Granular Activated Carbon

This is presented as a separate section despite previous mention under Filtration and Taste and Odor Control. This is done because it appears probable that removal of organics from public water supply sources will be of major professional and public concern over the coming years.

The need to remove organics not only applies to polluted surface water sources, but extends to protected surface waters and well supplies in addition, because oxidized organics related to cancer incidence can be formed by reaction of disinfectants and ubiquitous naturally-occuring organics as well as organics from waste contributions.

Further, it may be necessary in water treatment to use or to develop techniques for removal of organics by carbon adsorption that go far beyond the use of a few mg/l of powdered carbon in settling basins, or the conversion of conventional filter beds to include a shallow bed of granular carbon. It may be more appropriate to design special carbon contacting systems and carbon regeneration equipment specifically for this task of removing to a much higher degree all organic substances from water. These techniques may resemble to some extent those now used in the refining of sugar and in advanced wastewater treatment.

The Standards for water treatment aimed specifically at a very high degree of removal of organics rely heavily on pilot plant tests for each specific source of water to be treated, and draw heavily on the seven years of experience to date in the successful treatment of wastewaters by granular carbon adsorption. However, this experience must be further extended to meet the exacting requirements for water treatment.

3.13.2 Granular Activated Carbon Specifications

The important characteristics of a carbon must be expressed both in terms of adsorptive characteristics and physical properties. The adsorptive capacity of a carbon can be measured to a fair degree by determining the adsorption isotherm experimentally in the system under consideration. Simpler capacity tests such as the Iodine Number or the Molasses Number also may be used as a measure of adsorptive capacity, (III-15).

The adsorption isotherm is the relationship, at a given temperature, between the amount of a substance adsorbed and its concentration in the surrounding solution. If a color adsorption is taken as an example, the adsorption isotherm would consist of a curve plotted with residual color in the water as the abscissa, and the color adsorbed per gram of carbon as the ordinate. A reading taken at any point on the isotherm gives the amount of color adsorbed per unit weight of carbon, which is the carbon adsorptive capacity at a particular color concentration and water temperature. In very dilute solutions, such as water supplies, a logarithmic isotherm plotting usually gives a straight line.

From an isotherm test, it can be determined whether or not a particular purification can be effected. It will also show the approximate capacity of the carbon for the application, and provide a rough estimate of the carbon dosage required. Isotherm tests also afford a convenient means of studying the effects of pH and temperature on adsorption. Isotherms put a large amount of data into concise form for ready evaluation and interpretation. Isotherms obtained under identical conditions using the same test solutions for two test carbons can be quickly and conveniently compared to reveal the relative merits of the carbons.

For some applications, it is not necessary to know the complete adsorption isotherm to determine the best carbon for a particular application or to specify the most appropriate carbon. In these cases, it is possible to use simpler capacity tests such as the Iodine Number or Molasses Decolorizing Index as an appropriate measure of adsorptive capacity.

The Iodine Number is the number of milligrams of iodine adsorbed per gram of carbon when in equilibrium, under specific conditions, with a solution of 0.02 N iodine concentration.

The Iodine Number is an approximate measure of the adsorptive capacity of a carbon for small molecules such as iodine. The Molasses Decolorizing Index is, roughly, a measure of the adsorptive capacity of the carbon for color bodies in a specified molasses solution, as compared to a standard carbon. The Molasses Decolorizing Index is a measure, therefore, of the adsorptive capacity for large molecules, such as color bodies.

The physical properties of granular carbons which are important in performance include resistance to breakage, particle size, and degree of dustiness. For measuring resistance to breakage there are empirical tests such as Abrasion Number and Hardness Number. Particle size is determined by a screen analysis from which mean particle diameter and effective size can be calculated. Density is simply the weight per unit volume of the carbon. Specifications of a granular carbon suitable for water treatment filter applications are given in the Standards.

For incorporation in filter designs, carbon particle size distribution is very important. If the carbon is to replace anthracite coal in a dual media filter, it should have similar filtration characteristics and similar backwashing characteristics. Fortunately, commercial carbons are available with characteristics which are very similar to anthracite coals used as filter media.

The head loss through granular carbon is, of course, a function of the carbon size, the depth of the carbon layer, the hydraulic throughput rate, and the water temperature. Head loss data for commercial carbons in downflow service as a filter media following backwashing are available from manufacturers.

3.14.3 and 3.14.4 Contact Time and Carbon Bed or Column Design

Granular carbon can be used after conventional filtration of suspended matter or, as described hereafter, as a combination filtration-adsorption medium. Granular carbon has been utilized in conventional rectangular or circular rapid sand filters, in pressure vessels, and in specially designed adsorbers. The choice of equipment depends upon the severity of the organic removal problem, the availability of existing equipment, and the desired improvement of adsorption conditions.

Usually, two or more units are used in parallel downflow operation. The startups of the units are staggered so that the exhaustion of each bed will be in sequence. Blending of the fresh carbon effluent with partially exhausted carbon effluent in effect prolongs the life of the bed before reactivation or replacement of the individual beds is necessary.

Flow rates are 100 - 200 Lpd/Sq.M (2.5 to 5.0 gpm/ft^2) and bed depths vary from 0.8 to 3 meters (2.5 to 10 feet). Varying the combined values of these two factors adjusts the contact time of the water and the granular carbon beds. A direct linear relationship between contact time and carbon bed performance has been found in full-scale plant tests and concurrent small column tests.

Carbon performance at a given contact time has been found to be unaffected by variations in hydraulic loading rates in the 80 - 400 Lpd/Sq.M (2 - 10 gpm/ft^2) range. Thus, in terms of adsorption only, contact time is the governing criteria and not surface loading rate within the ranges of practicality.

When the granular carbon bed is functioning both as a turbidity removal and adsorption unit, there may be reasons to limit the bed depth and flow rate parameters to remove effectively turbidity and to backwash properly the filter. If granular activated carbon is to be effective in turbidity removal, it must be hard enough to withstand vigorous backwash agitation. At the same time, it should be dense enough to expand during the backwash cycle and to settle quickly for immediate resumption of filtration. As discussed earlier, coal-based granular carbon possesses approximately the same density and filtration characteristics as anthracite, which has found increasingly wider use in the water field.

Particle size of the carbon, in addition to contact time, should be considered carefully as a design factor. Reduction of particle size for a given set of flow conditions is a means of increasing adsorption rates and, thereby, improving adsorption performance. Reduction in particle size to improve adsorption must be consistent with other significant factors such as head loss and backwash expansion. Length of filter run in an adsorption-filtration bed would also be a problem, if too small a particle size were chosen.

Where existing rapid sand filters are being converted to adsorption-filtration units, the permissible depth of the carbon layer will be limited by the freeboard available in the existing structure. Adequate space between the carbon surface and the wastewater troughs should be available to permit at least 30 percent expansion of the carbon layer.

For the design of special contactors for longer detention periods refer to: EPA, "Process Design Manual for Carbon Adsorption", U.S. Environmental Protection Agency. Technology Transfer, Washington, D.C., October, 1973.

3.13.5 Carbon Regeneration

The requirements for granular carbon regeneration and reuse in the water works industry will be less severe than those prevailing in existing wastewater reclamation facilities, and the design criteria for wastewater may be projected with a high degree of confidence to the new application of these processes.

In granular carbon regeneration the adsorbed organics are driven from the granular carbon by heating the carbon to temperatures above 660°C (1500°F) in a multiple hearth furnace. Spent carbon is typically removed from the carbon bed in a slurry, dewatered by gravity drainage to a storage vessel, fed into the furnace where the regeneration occurs, water quenched as it leaves the furnace, and is then stored or returned to the carbon filter. Carbon losses of 5 - 8 percent per regeneration cycle can be maintained.

Whether or not carbon regeneration is practical is dependent upon the plant capacity and the carbon dosages required to achieve the desired water quality. The smallest commercial furnaces have capacities of 1125 to 1575 Kg (2500 to 3500 lb per day). Table 3.13.5-A summarizes the reactivation requirements for various carbon dosages for a 38 million Lpd (10 mgd) plant. As tertiary treatment of secondary sewage effluents usually requires only 27 to 38 Kg/million L (250-350 lb per million gal.), it is apparent that the upper limit of this table represents very severe operating conditions. It is also apparent that even a small regeneration furnace is adequate for most 30 - 70 million Lpd (10 - 20 mgd) water treatment plants.

For cases where very low carbon dosages are adequate, single use of the carbon may be economically acceptable. Shipping spent carbon to a central regeneration facility may be practical in some areas.

Table 3.15.5-A REGENERATION REQUIREMENTS FOR A 38 MILLION Lpd (10 MGD) PLANT AT VARIOUS CARBON DOSAGES

Carbon Dosage		Carbon Regenerated Per Year	
lb/mg	mg/l	lb.	Kg
38	4.6	140,000	63,000
58	7	210,000	94,500
115	14	420,000	189,000
330	28	840,000	378,000

3.14.0 Activated Carbon for Dechlorination of Waters

Carbon has been used for over half a century to dechlorinate water, the early systems using granular coal and coke.

The process of chlorine removal from water is not a pure adsorption process but also involves a chemical reaction between the chlorine and the water. The initial step is the adsorption of chlorine in the form of hypochlorous acid on the carbon surface. The subsequent decomposition of the hypochlorous acid results in the formation of hydrochloric acid and nascent oxygen.

The basic parameters related to the operation of an activated carbon dechlorinator are: (1) chemical state of the free chlorine, (2) pH, (3) inlet chlorine concentration, (4) flow rate through the carbon bed, (5) particle size of the carbon, (6) type of carbon, (7) temperature,(8) manner of operation (continuous or interrupted), and (8) impurities present.

The chemical state of the free chlorine is one of the strong influencing factors of the dechlorination process and any evaluation of activated carbon should be subjected to the same chlorine forms, or the pH should be adjusted.

Dechlorination efficiency for any activated carbon is also strongly dependent on particle size, and the smallest mean particle size should be selected for any carbon grade. The limiting factor in such a selection is the maximum allowable pressure drop. The micro- and macroporosity of the carbon also influence dechlorination efficiency. Since the dechlorination process is related to the surface area of the carbon, macropores are necessary to make the high surface areas accessible for the adsorption reaction. The raw material from which the carbon is made generally does not have any affect on dechlorination efficiency.

The presence of colloidal impurities or high organic concentrations can substantially reduce the carbon useful life as a dechlorinator. The colloids may plug the pores of the carbon, reducing the surface area available for dechlorination. Organics can form an adsorbate film on the carbon, causing the same end result. If pretreatment steps are adequate to remove these impurities, beds of activated carbon will have a long useful life as a dechlorinating bed.

If the experimental conditions are carefully selected so that they match the expected operating conditions, then it is fairly straightforward to evaluate activate carbon to dechlorination and to size the adsorber.

The life of the carbon in dechlorination service is extremely long. For example, under conditions of sand filter service that is, 100 Lpm/Sq.M (2.5 gpm/sf) 0.75 M (2.5 ft.) bed depth, granular carbon medium in a 3.79 million Lpd filter 20 Cu.M (700 ft.^{3}) on dechlorination service alone could process 2650 million liters (700 million gal.) of 4 ppm free-chlorine influent water before a breakthrough of 0.01 ppm chlorine would be reached. A bed processing water containing 2 ppm chlorine under similar conditions would last about 6 years. The effect of mesh size is pronounced. A reduction in particle size from 8 x 30 to 14 x 40, allows a doubling of flow rate without a sacrifice in efficiency.

Dechlorination will proceed concurrently with adsorption of organic contaminants. Long-chain organic molecules, such as those of detergents, will reduce dechlorination efficiency somewhat, but many common water impurities, such as phenol, have little apparent effect upon the dechlorination reaction.

A rise in temperature within the normal range for water of 0 to 20^{o}C, and a lowering of pH, say from 9 to 7 improve dechlorination efficiency.

SUMMARY OF STANDARDS FOR CHEMICAL APPLICATION

4.0.0 General (III-20)

No chemicals should be applied to treat drinking waters unless specifically permitted by the State.

4.0.1 Plans and specifications should be submitted for review and approval, and should include:

- a. descriptions of feed equipment, including maximum and minimum feed ranges and accuracy,
- b. location of feeders, piping layout and points of application,
- c. storage and handling facilities,
- d. specifications for chemicals to be used,
- e. operating and control procedures,
- f. descriptions of testing equipment and procedures,
- g. information on source of chemicals and transportation to plant.

4.0.2 Chemicals should be applied to the water at such points and by such means as to

- a. assure maximum efficiency to treatment,
- b. assure maximum safety to the consumer,
- c. provide maximum safety to operators,
- d. provide maximum flexibility of operation through various points of application, when appropriate (chlorine to raw water, filter influent, and effluent, and clear well - polymer to rapid mix, flocculator, and filter influent),
- e. prevent backflow or back-siphonage between multiple points of feed through common manifold (see EPA, "Cross Connection Control Manual, 1973").
- f. prevent clogging, deterioration, or malfunctioning of valves, sluice gates, or other equipment (for example, do not add lime just upstream from a sluice gate), and

g. facilitate cleaning and maintenance, and proper mixing of chemicals and water.

4.1.0 Feed Equipment

4.1.1 Number of Feeders

a. Where chemical feed is recommended for the protection of the supply, such as disinfection, coagulation or other essential process

1. a minimum of two feeders should be provided;

2. a standby unit or combination of units of sufficient capacity should be available to replace the largest unit during shut-downs.

b. Spare parts should be available for all feeders to replace parts which are subject to wear and damage.

4.1.2 Design and Capacity - Design and capacity should be such that

a. Feeders will be able to supply, at all times, the necessary amounts of chemical at an accurate rate (± 3%) throughout the range of feed.

b. Proportioning of chemical feed to flow rate should not be provided. The Rationale Section states that is is not necessary if a plant operates at a constant flow rate. This is one consideration, however fully as important in maintaining proper chemical treatment is the dose based on the water conditions. This is not necessarily the same over any time period even if the flow rate is constant. This criteria should not be a blanket coverage but must be investigated for each chemical used at each treatment plant.

c. Positive displacement type solution feed pumps should be used to feed liquid chemicals.

d. Chemical solutions cannot be siphoned into the water supply, by

1. assuring discharge at point of positive pressure, or

2. providing vacuum relief, or

3. providing a suitable air gap, or

4. other suitable means or combinations as necessary.

e. Service water supply cannot be contaminated by chemical solutions, by

    1. equipping the supply line with backflow or backsiphonage prevention devices, or

    2. providing an air gap between supply line and solution tank.

f. Chemical-contact materials and surfaces are resistant to the aggressiveness of the chemical solution.

g. Dry chemical feeders will

    1. measure chemicals volumetrically or gravimetrically, within an accuracy range of ± 5%,

    2. provide effective solution of the chemical in the solution pot,

    3. preferably provide gravity feed from solution pots,

    4. completely enclose chemicals to minimize emission of dust to the operating room.

h. No direct connection exists between any sewer and a drain or overflow from the feeder or solution chamber or tank.

4.1.3 Location - Chemical feed equipment should

a. be conveniently located near points of application to minimize length of feed lines;

b. be readily accessible for

    1. servicing and repair, and

    2. observation of operation;

c. be located and protective curbings provided so that chemicals from equipment failure, spillage or accidental drainage will not enter the water in conduits, treatment or storage basins.

4.1.4 Control

a. Feeders may be manually or automatically controlled, with automatic control capable of reverting to manual control as necessary.

b. Process should be manually started following shutdown, unless otherwise approved by the State.

c. Feed rates proportional to flow should be provided.

d. Automatic chemical dose or residual analyzers may be approved for use and should provide

   1. alarms for critical values, and

   2. recording charts, or a digital readout with computerized data logger.

4.1.5 Solution Tanks

a. Means should be provided in a solution tank to maintain uniform strength of solution, consistent with the nature of the chemical solution; continuous agitation is necessary to maintain slurries in suspension.

b. Two solution tanks may be required for a chemical, of specific capacity, to assure continuity of supply in servicing a solution tank.

c. Each tank should be provided with a drain;

   1. No direct connection between any tank or drain and a sewer should be permitted, and

   2. any drain should terminate at least two pipe diameters above the overflow rim of a receiving sump, conduit or waste receptacle.

   3. In no case should drains discharge directly into sewers, streams, or treatment flow. Preferably materials should drain to a sump from which it can be disposed of safely or recovered for further use.

d. Means should be provided to indicate the solution level in the tank.

e. Make-up water should enter the tank from above the maximum solution level, a distance of two pipe diameters but not less than six inches, or be protected with approved backflow prevention devices.

f. Chemical solutions should be kept covered.

   1. Polyphosphate solutions should be disinfected by carrying approximately 10 mg/l chlorine residual.

   2. Large tanks with access openings should have such

openings curbed and fitted with tight covers.

g. Subsurface locations for solution tanks should

   1. be free from sources of possible contamination,

   2. assure positive drainage for ground waters, accumulated water, chemical spills and overflows.

h. Overflow pipes, when provided, should

   1. be turned downward, with end screened,

   2. have free discharge, and

   3. be located where noticeable.

4.1.6 Weighing Scales should be

a. provided for weighing cylinders, at all plants utilizing chlorine gas; for large plants, indicating and recording type are desirable;

b. provided for fluoride solution feed;

c. provided for volumetric dry chemical feeders;

d. accurate to measure increments of 0.5 per cent of load.

4.1.7 Feed Lines should

a. be as short as possible in length of run, and

   1. of durable, corrosion resistant material,

   2. easily accessible throughout entire length,

   3. protected against freezing, and

   4. readily cleanable;

b. slope upward from chemical source to feeder, when conveying gases;

c. introduce corrosive chemicals so as to minimize potential for corrosion through use of ample dilution water and diffuser systems;

d. be designed to avoid scale-forming or solids deposition by the water, chemical, solution or mixture conveyed;

e. carry chlorine gas directly to chlorine feeder room and not pass through critical areas.

4.1.8 Service Water Supply

a. Water used for dissolving dry chemicals, diluting liquid chemicals or operating chemical feeders should be

1. only from a safe, approved source,

2. protected from contamination by appropriate means,

3. ample in supply and adequate in pressure,

4. provided with means for measurement when preparing specific solution concentrations by dilution,

5. properly treated for hardness, when necessary.

b. Where a booster pump is required, duplicate equipment should be provided and, when necessary, standby power.

c. Back-flow prevention should be achieved by appropriate means such as

1. an air gap between fill pipe and maximum flow line of solution or dissolving tank equivalent to two pipe diameters but not less than 15 cm (6 in.), or

2. an approved reduced pressure zone backflow preventer, consistent with the degree of hazard, aggressiveness of chemical solution, back pressure sustained, and available means for maintaining and testing the device, or

3. a satisfactory vacuum relief device.

4.2.0 Chemicals(III-20)

4.2.1 Quality

a. Chemical containers received at the plant should be fully labeled as required by ICC regulations to include

1. chemical name, purity and concentration, and

2. supplier name and address; however this is not mandatory within the plant on storage bins or tanks.

b. Chemicals should meet American Water Works Association specifications, where applicable. (See 4.2.1 Chemicals, Rationale)

c. Chemicals should be assayed for conformance to contract specifications.

d. Chemicals having a distinguishing color may be used, providing the coloring material is not toxic in concentrations used and will not impart taste, odor or color to the water supply.

4.2.2 Storage

a. Space should be provided for

   1. at least thirty days of chemical supply, or a minimum of 1½ truck loads storage volume, whichever is greater,

   2. convenient and efficient handling, and

   3. dry storage conditions.

b. Cylinders or other containers of chlorine gas should be

   1. isolated from operating areas,

   2. restrained in position to prevent upset,

   3. stored in rooms separate from ammonia storage.

   4. also, see "Chlorine Manual", The Chlorine Institute, N.Y. for further precautions, and for handling tank cars and tank barges.

c. Liquid chemical storage tanks should have

   1. a liquid level indicator,

   2. an overflow and a receiving basin capable of holding 110% of the stored volume, or drain capable of receiving accidental spills or overflows.

d. Special precautions should be taken with

   1. sodium chlorite, to eliminate any danger of explosion;

   2. activated carbon, which is a potentially combustible material, requiring isolated, fireproof storage and explosion-proof electrical outlets, lights and motors in areas of dry handling.

e. Chemicals should be stored in covered or unopened shipping containers, unless the chemical is transferred into an approved covered storage unit.

f. Solution storage or day tanks supplying feeders directly should have sufficient capacity for one day of operation.

g. Acid storage tanks should be vented to the outside atmosphere, but not through vents in common with day tanks.

4.2.3 Handling

a. Provisions should be made for measuring quantities of chemicals used to prepare feed solutions.

b. Storage tanks and pipelines for liquid chemicals should be specific to the chemicals and not for alternates.

c. Chemicals that are incompatible should not be fed, stored or handled together.

d. Provision should be made for the proper transfer of dry chemicals from shipping containers to storage bins or hoppers, in such a way as to minimize the quantity of dust which may enter the room in which the equipment is installed; control should be provided by use of

1. vacuum pneumatic equipment or closed conveyor systems, or
2. facilities for emptying shipping containers in special enclosures, or
3. exhaust fans and dust filters which put the hoppers or bins under negative pressure.

e. Precautions should be taken with electrical equipment to prevent explosions, particularly in the use of sodium chlorite and activated carbon.

f. Acids should

1. be kept in closed, acid-resistant shipping containers or storage units;
2. not be handled in open vessels, but should be pumped in undiluted form from original containers, through suitable hose, to the point of treatment or to a covered day tank.

g. Carts, elevators and other appropriate means should be provided for lifting and moving chemical containers to minimize handling by operators.

h. Provisions should be made for disposing of empty bags, drums or barrels, either by burning or by some other approved procedures which will minimize exposure to dusts.

i. Provision should be made for proper transfer of dry chemicals from storage to the chemical feed device, in such a way as to minimize the quantity of dust which may enter the room. Gravity and conveyor systems should be dust-tight and adequate ventilation provided.

j. Provide means for safe conveyance and handling of highly concentrated liquid chlorine solutions.

k. Provide vibators on bulk storage tanks to prevent bridging of material.

4.3.0 Housing(III-20)

a. Structures, rooms and areas accommodating chemical feed equipment should provide convenient access for

   1. servicing and repair;

   2. observation of operation.

b. Floor surfaces should be smooth and impervious, slip-proof and well-drained.

c. Open basins, tanks and conduits should be protected from chemical spills or accidental drainage.

d. Chlorine gas feed and storage should be

   1. enclosed, separated, and preferably downwind from other operating areas in order to prevent injury to personnel and damage to equipment; separate chlorine feed and storage may be required for large installations;

   2. provided with an inspection window to permit viewing of the interior of the room and the equipment;

   3. provided with doors assuring ready means of exit; doors opening to the building exterior should be provided.

e. Where chlorine gas is used, ventilation for each room should be provided for one complete air change per minute; and

   1. the air outlet from the room should be near the floor and the point of discharge shall be so located as not to contaminate air inlets to any rooms or structures, or adversely affect the surrounding environment;

2. air inlets should be through louvers near the ceiling, and temperature controlled to prevent adverse affect on chlorinators;

3. switches for fans and lights should be outside of the room, at the entrance; signal light, indicating fan operation, should be provided at each entrance when fan can be controlled from more than one point;

4. vents from feeders and storage should discharge to the outside atmosphere, above grade.

f. Chlorinator rooms should be heated to (16°C), but should be protected from excess heat; cylinders and gas lines should be protected from temperatures above that of the feed equipment.

g. Pipes and feed lines through interior walls should be sealed with non-shrink grout or other positive means.

4.4.0 Operator Safety(III-20)

a. Gases from feeders, storage and equipment exhaust should be conveyed to the outside atmosphere, above grade and remote from air intakes.

b. Special provisions should be made for ventilation of chlorine feed and storage rooms.

c. Gas masks of the cannister type, designed for chlorine gas and meeting the requirements of the U.S. Bureau of Mines, should be available at all installations where chlorine gas is handled, and should be stored outside every room where chlorine is used or stored; as an alternate, oxygen-supplying equipment or air-supplying equipment may be considered or required by the State. Escape gas masks should be carried by all operating and maintenance personnel who enter chlorine feed and storage areas.

d. A bottle of ammonium hydroxide should be available for chlorine leak detection; where ton cylinders are used, leak repair kits should be provided.

e. A plastic bottle of hydrochloric acid (muriatic acid, in commercial form) should be available for ammonia leak detection where ammonia gas is used or stored.

f. At least one pair of rubber gloves with long gauntlets, a dust respirator of a type approved by the U.S Bureau of Mines for toxic dusts, and an apron or other protective clothing should be provided for each operator in any shift who will handle dry chemicals.

g. Rubber gloves, clothing protection and goggles should be provided for each operator preparing chemical solutions.

h. Facilities should be provided for washing of face, gloves and protective equipment.

4.5.0 Hazardous Material Handling and Spills(IV-15)

Safety provisions in handling hazardous materials and reporting spills of hazardous materials should be in accordance with Federal Standards as described in "Field Detection and Damage Assessment Manual for Oil and Hazardous Material Spills", by the Environmental Protection Agency Division of Oil and Hazardous Materials, June 1972.

RATIONALE FOR CHEMICAL APPLICATIONS STANDARDS

4.1.0 Feed Equipment

4.1.1 Number of Feeders

In order to assure an uninterrupted supply of water to consumers, it is necessary to make provisions for equipment failures and shut-downs for repairs. Certain chemical feeders such as those involved in disinfection, coagulation and other essential processes are necessary to proper protection of the supply. In order to provide for standby service, a minimum of two feeders should be provided with the capacity of the standby unit or units being equal to that of the largest single unit installed for the service. In addition, spare parts should be stocked at the plant for those chemical feeder parts that are subject to wear or damage.

4.1.2 Design and Capacity

To fulfill their intended function, chemical feeders should have sufficient capacity to feed the amount of material required by the combination of maximum flow and maximum dosage.

Proportioning of chemical feed to rate of flow is a simple reliable process and should be included unless the plant always operates at a constant rate of flow for periods of 12 hours or more at a time.

Precautions against siphonage and backflow, and measurements of chemicals fed are recommended to avoid excessive dosage or localized high concentrations of chemicals in the water.

4.1.3 Location

Short feed lines minimize plugging problems and downtime for cleaning. Lime slurry conduits are particularly troublesome, and open channels or other facilities which are easily cleaned are recommended. Easy access and observation make it more likely that the chemical feed equipment will be operated properly.

It should not be possible to introduce excessive amounts of chemicals into the water through the rupture or leakage of storage tanks or pipelines.

4.1.4 Control

The control standards are aimed at making it easier to operate the chemical feed equipment properly than improperly, and at calling operator attention to unusual events.

Preceding page blank

4.1.5 Solution Tanks

Some slurries like lime slurry tend to change strength because of sedimentation of solids if not continuously stirred or otherwise agitated or mixed.

Chemical solutions should be protected against contamination, backflow, overflow, and accidental discharge as provided by the standards.

4.1.6 Weighing Scales

These are recommended in order to properly anticipate exhaustion of chemical supplies and to assure proper chemical dosage.

4.1.7 Feed Lines

These standards are intended to facilitate proper operation and improve safety.

4.1.8 Service Water Supply

The purpose of these standards are twofold: to protect the service water supply against chemical contamination, and to provide the treated water with the right amount and concentration of chemical.

4.2.0 Chemicals

4.2.1 Quality

The purity and concentration of most chemicals used in water systems are covered by AWWA Standards as follows:

TREATMENT CHEMICAL	AWWA STD. NO.
Sodium Chloride	B200-69
Soda Ash	B201-59
Quicklime and Hydrated Lime	B202-65
Hypochlorites	B300-64
Liquid Chlorine	B301-59
Sodium Chlorite	B303-67
Ferrous Sulfate	B402-68
Aluminum Sulfate	B403-70
Liquid Sodium Silicate	B404-58
Sodium Aluminate	B405-60
Ferric Sulfate	B406-64
Trisodium Phosphate	B500-66
Caustic Soda	B501-64

TREATMENT CHEMICAL	AWWA STD. NO.
Sodium Hexametaphosphate	B502-67
Powdered Activated Carbon	B600-66
Sodium Pyrosulfite	B601-64
Copper Sulfate	B602-59
Potassium Permanganate	B603-68
Sodium Flouride	B701-71
Sodium Silicoflouride	B702-71
Hydrofluosilicic Acid	B703-71
Granular Activated Carbon	B604-74

Coagulant aids (polymers) for water treatment are reviewed and approved by the EPA on the basis of information submitted by manufacturers and distributors, and lists of approved products are published periodically in the Journal of the American Water Works Association (see JAWWA, p. 735, Nov. 1973).

4.2.2 Storage

Chemical storage should be adequate for normal time between shipments, for interruption in shipments due to delays, strikes, weather, and the like. Special precautions should be taken in consideration of the properties of certain chemicals to assure safety and proper preservation against loss of effectiveness.

4.2.3 Handling

The standards for handling of dry chemicals and chemical solutions are intended to assure proper dosage, reduce dust problems, avoid accidents, and assure operator safety.

4.3.0 Housing

The housing requirements are intended to protect against loss or contamination of chemical, and to provide convenience and safety for plant operators and the public.

4.4.0 Operator Safety

These standards prescribe safety equipment which should be made available to plant operators as well as provisions for ventilation of chemical feed and storage rooms.

4.5.0 Hazardous Material Handling and Spills

The Federal Standards, set forth by the EPA in "Field Detection and Damage Assessment Manual for Oil and Hazardous Material Spills (June 1972)", cover the full range of incidents related to the water works field. They give step by step instructions on what to do from the time of occurence until a full damage assessment plan is in operation. They tell what to use in locating a spill and making presumptive identification. They prescribe general principles on how and where to collect samples. They give methods for biological investigation. They suggest a systematic approach for field investigation of damage assessment. They comment on the use of statistics in the field, and they provide a checklist of rules for meeting legal requirements and of details to be included in a damage report.

SECTION V PUMPING FACILITIES

SUMMARY OF STANDARDS - PUMPING FACILITIES

5.0.0 General (III-20)

Pumping facilities should be designed to maintain the sanitary quality of pumped water. Subsurface pits or pump rooms and inaccessible installations should be avoided. No pumping station should be subject to flooding.

Pumps are subject to outage due to wear, breakdown, or power loss, and may be responsible for low distribution system pressures. Elevated storage should be used wherever possible in lieu of booster pumps to obtain greater reliability.

5.1.0 Location (III-20)

The pumping station should be so located that the proposed site will meet the requirements of the sanitary protection of the water quality, hydraulics of the system, and be protected against interruption of service by fire, flood, or any other hazard.

5.1.1 Site Protection - The station should be:

a. elevated to a minimum of 30 cm (one foot) above 100-year flood elevation, or protected to such elevation;

b. accessible at all times unless permitted to be out of service for periods of inaccessibility;

c. graded around station so as to lead surface drainage away from the station;

d. protected to prevent vandalism and entrace by unauthorized persons or animals.

5.1.2 Selection

The selection of sites from those which are properly protected is influenced by the site location relative to water source and points of delivery, by the availability of utility services, and the availability of land for future expansion. See Section I, Site Selection.

5.2.0 Ground Water Facilities

Where pumping facilities are used, wells and springs should be vented by properly hooded and screened pipe extending at least 30 cm (12 inches) above the pump floor or ground surface. Where necessary, provision should be made for lubricating the pump from a point at least 15 cm (6 inches) above the top of the well cover, by means which will prevent contamination of the water supply.

5.2.1 Sanitary Protection (Also see Section 2.4.0)

5.2.1.1 Dug Wells - Pumping stations located over dug wells should have a watertight concrete floor. Entrance hatch in the pump floor should:

a. be located adjacent to and inside of the well perimeter;

b. have a curb at least 10 cm (4 inches) high;

c. have edge of cover extending down over the curb at least 5 cm (2 inches);

d. be kept locked when not in use.

5.2.1.2 Driven or Drilled Wells - Pumping stations located over driven wells should:

a. have riser pipe or casing extending at least 15 cm (6 inches), and preferably 30 cm (12 inches), above the floor, and be equipped with flange or suitable stuffing box;

b. have riser pipe or casing firmly connected to the pump structure or have casing inserted into a recess extending at least 2.5 cm (1 inch) into the base of the pump, if a watertight connection is not provided;

c. have base of pump not less than 15 cm (6 inches) above pump room floor;

d. have pump foundation and base design to prevent water from coming into contact with the joint.

5.2.1.3 Submersible Pumps - Where a submersible pump is used, the top of the casing should be effectively sealed against entrance of water under all conditions of vibration or movement of conductors or cables.

5.2.1.4 Discharge Piping - Discharge piping should be provided with means to pump to waste but shall not be directly connected to a sewer. The discharge line should:

- a. have control valves located above pump floor;
- b. be protected against freezing;
- c. be valved to permit testing and control of each well;
- d. have watertight joints;
- e. have all exposed valves protected against breakage and freezing;
- f. have a flexible coupling installed in the discharge line near the pump.

5.2.2 Well Construction

The standards for well construction are given in Section 2.4 of this Manual. For further details and more information on the construction of dug, bored, driven, drilled, and radial wells, please refer to Chapter 4 of AWWA Manual No. M21, "Ground Water".

5.2.3 Well Pumps

5.2.3.1 Certified Pumps

Deep well vertical turbine pumps are used in the great majority of well installations for public supplies. These pumps should comply with the requirements set forth by the AWWA in their Standard No. E101 - 71, "American National Standard for Deep Well Vertical Turbine Pumps - Line Shaft and Submersible Types" and Appendix A, "Field Testing of Deep Well Turbine Pumps".

Horizontal centrifugal pumps for wells are limited to a single stage and thus to depths of less than 6 meters (20 feet). Horizontal centrifugal pumps should always be installed under positive suction head.

Submersible pumps offer several advantages: (1) they are suited for installation in crooked wells; (2) wells subject to flooding can be completely sealed; (3) a minimum amount of surface equipment is needed, and (4) operation is silent.

Propellor and mixed flow pumps may be used to pump large quantities of water against low heads, generally where flow is greater than 1,135 Lpd (300 gpm) and at heads under 12 meters (40 feet).

5.2.3.2 Jet Pumps - This type of pump is a combination of a centrifugal pump and an ejector and has application in shallow wells and for small capacities.

5.2.3.3 Air Lift Pumps - With this type of pump air is mixed with water to reduce the specific gravity of the water to the point where it will rise inside a submerged pipe. An adequate supply of air must be properly mixed with the water and must be introduced at the right depth of submergence, usually at a point about 40 to 60 percent of the total life measured from the static water level in the well. Advantages of air lift pumps are their simplicity, that they can be used in crooked, small diameter deep wells, and, that there are no moving parts within the well which have to be maintained, adjusted, or removed.

5.2.3.4 Rotary Pumps - These pumps have rotating elements in a case, but operate without centrifugal action. They are self-priming and will operate under difficult suction conditions. They wear rapidly in water containing sand, and are not recommended for such service. There are two types of rotary displacement type pumps, one employs rotary gears, the other employs a helical stator and a helical rotor.

5.2.3.5 Reciprocating Pumps - This type of pump is theoretically suitable for pumping wells of any depth, such depth being limited practically by strength of material, power source, and economics. Maximum suction lift is limited to 4.5 meters (15 feet) or less. One objectionable feature of reciprocating pumps is the uneven flow produced.

5.2.3.6 Desirable Operating Conditions

The net positive suction head (NPSH) of the proposed pump installation should be greater than the required NPSH of the pump under all operating conditions.

Pump installations should be planned to prevent possible cavitation. For centrifugal pumps avoid the following conditions:

a. speeds higher than manufacturer's recommendations.

b. excessive suction lift

c. heads much lower than head at peak pump efficiency.

d. capacity much higher than capacity at peak pump efficiency.

Continuous pumping is preferable to stopping and starting. The pumping rate should be such as to minimize the number of on-off cycles. No period of operation should be less than 15 minutes.

If pump characteristics may allow development of excessive pressures or overheating due to excess flow at low pressures, special precautions should be taken such as: the use of pressure relief valves, automatic by-passes, or bleeder lines, or the installation of temperature sensing and alarm systems.

5.2.3.7 Power Requirements

The horsepower required to drive a pump depends on the flow of water and the pumping head. Power units should be sized to operate without overload under all possible combinations of flow and head from no flow to maximum flow at any head from zero to shut-off head.

5.2.3.8 Drives

Pumps may be driven by electric motor, steam turbines, or by oil, gas, or gasoline engines. Drives may be direct or by power transmission. Properly designed belt or chain drives are acceptable. Richt angle gear drives are useful, particularly for connecting power from two sources such as an electric motor drive and a standby engine drive, so that either can be selected through a clutch arrangement.

5.2.3.9 Pump Selection and Installation

Some factors to be considered in selecting a pump for a particular well installation are: (1) capacity, (2) depth of well and pumping level, (3) inside diameter of well, (4) condition of bore, whether straight or crooked, (5) abrassive properties of water (sand), (6) total head, (7) type of power available, and (8) costs.

5.2.3.10 Pump Testing

It is recommended that field testing of well pumps be conducted in accordance with Appendix A, "Field Testing of Deep Well Turbine Pumps", AWWA Standard E101 - 71.

5.3.0 Surface Water Facilities(III-20)

Pump stations normally associated with surface water sources, either as raw or finished water pump stations, should:

a. have adequate space for the installation of additional units if needed, and for the safe servicing of all equipment;

b. be of durable character, fire and weather resistant and with outward opening doors;

c. have floor elevation of at least 15 cm (6 inches) above finished grade;

d. have underground structure waterproofed;

e. have all floors drained without impairing the quality of water being handled and if equipment is contained on the floor, the floor should slope to the point of drainage;

f. provide suitable outlet for drainage from pump glands without discharging onto the floor.

5.3.1 Suction Well - Suction wells should:

a. be watertight;

b. have floors sloped to permit removal of water and entrained solids;

c. be covered or otherwise protected against contamination, including pump lubricants.

5.3.2 Equipment Servicing - Pump stations should be provided with:

a. crane-ways, hoist beams, eyebolts, or other adequate facilities for servicing or removal of pumps, motors or other heavy equipment;

b. openings in floors, roofs or wherever else needed for removal of heavy or bulky equipment;

c. a convenient tool board or other facilities, as needed for proper maintenance of the equipment.

5.3.3 Stairways and Ladders - Stairways or ladders should:

a. be provided between all floors, in pits or compartments which must be entered;

b. have handrails on both sides, and treads of nonslip material.

Stairs are preferred in areas where there is frequent traffic or where supplies are transported by hand. They shall have risers not exceeding 23 cm (9 inches) and treads wide enough for safety.

5.3.4 Heating - Provisions should be made for adequate heating for:

a. the comfort of the operator;

b. the safe and efficient operation of the equipment.

In pump houses not occupied by personnel, only enough heat need be provided to prevent freezing of equipment.

5.3.5 Ventilation - Ventilation should conform to existing local and/or state codes. Adequate ventilation should be provided for all pumping stations. Forced ventilation of at least six changes of air per hour should be provided for:

a. all rooms, compartments, pits and other enclosures below grade floor;

b. any area where unsafe atmosphere may develop or where excessive heat may be built-up.

5.3.6 Dehumidification - In areas where excess moisture could cause hazards to safety or damage to equipment means for humidification should be provided.

5.3.7 Lighting - Pump stations should be adequately lighted throughout. All electrical work should conform to the requirements of the American Insurance Association and related agencies to the National Electric Code and to relevant State and/or local codes.

5.3.8 Sanitary and Other Conveniences - Except in the cases of small automatic stations or where such facilities are otherwise available, all pumping stations should be provided with potable water, lavatory and toilet facilities. Plumbing should be so installed as to prevent contamination of a public water supply. Wastes should be discharged in accordance with the Standards in this Manual (see Section 1.6).

5.3.9 Pumps - At least two pumping units should be provided except where ample time will be available between pumping periods for necessary repairs. If only two units are provided, each should be capable of carrying the peak demand plus fire requirements. The pumping units should:

a. have ample capacity to supply the peak demand plus fire requirements without dangerous overloading;

b. be driven by a prime mover able to operate against the maximum head and air temperature which may be encountered;

c. have spare parts and tools readily available.

5.3.10 Suction Lift - Suction lift should:

a. be avoided, if possible;

b. be within allowable limits, preferably less than 4.5 meters (15 feet).

If suction lift is necessary, provision should be made for priming the pump.

5.3.11 Priming - Prime water should not be of lesser sanitary quality than that of the water being pumped. Means should be provided to prevent backsiphonage. When an air-operated ejector is used, the screened intake should draw clean air from a point at least 3 meters (10 feet) above the ground or other source of contamination, unless the air is filtered by apparatus approved by the State. Vacuum priming may be used.

5.4.0 Booster Pumps(III-20) Booster pumps should be located or controlled so that:

a. they will not produce negative pressure in their suction lines;

b. the intake pressure is at least 1.4 Kg/Sq. cm (20 psi) when pump is in normal operation;

c. automatic cutoff pressure is at least 0.35 Kg/Sq. cm (5 psi) in the suction line;

d. automatic or remote control devices have a range between the start and cutoff pressure which will prevent excessive cycling.

5.4.1 Inline Booster Pumps - In addition to the other requirements of this section, inline booster pumps should be readily accessible for servicing and repairs.

5.5.0 Selection of Pumps for Surface Water Facilities and Booster Service (IV-7,12,20)

5.5.1 Pump Types - Pumping equipment for general water service can be divided into two general classes, centrifugal and displacement. Single stage and multistage centrifugals are now almost universally used. Displacement pumps can be of the piston or plunger type, but are rapidly becoming obsolete.

For desirable operating conditions refer to Section 5.2.3.6.

5.5.2 Booster Pumps - Booster pumps may be used to increase pressures in parts of water distribution systems by taking suction from a main or reservoir in one part of the system at low pressure and discharging it into another part of the system or into a storage reservoir or elevated tank at a higher pressure. When discharging into a reservoir or tank, constant speed centrifugal pumps may used. When discharging directly into a closed pipe system, variable speed drives are recommended.

5.5.3 Pump Selection Criteria

5.5.3.1 Capacity - Capacity requirements are affected by present and future water demands on the system served by the pump station, the number of pumps to be installed, and the range of present and future operating conditions anticipated. A pump should be selected which will operate alone or in parallel with other pump units when required, and at maximum operating efficiency over the range of head and flow conditions.

5.5.3.2 Characteristic Curves - Each centrifugal pump has its own characteristics which can be represented by three curves, one each for head-capacity, brake-horsepower, and efficiency. A study of these sets of curves for various pumps will reveal the best pump for the job to be done. There are a number of pumps which can be furnished to meet a given head-capacity specification. But the pump must also fit into the system and be able to operate in its confines. The slope of the head-capacity curve should be matched to the situation. If there are requirements for variable flows and discharge pressures, a pump with a steep head capacity curve is advantageous. For constant head and discharge, a pump with a flat curve is needed. The power and efficiency curves will give information on variations of these characteristics over the range of discharges. If pumps cannot be found to fit the requirements at a common motor speed, then pumps with variable-speed drives may be advisable.

It is good practice to select a pump with an impeller that is smaller in diameter than the maximum impeller size for that pump, so that a larger impeller can be installed when water demands increase. It may also be desirable to oversize the motor in the original installation as a further provision towards future use of a larger impeller. The pump will not use any more power than required by the conditions under which it operates, regardless of the motor size. Motor efficiencies vary little between 3/4 and full load. However, they do drop rapidly at 1/2 load or overload, so that overloading or excessive oversizing should be avoided.

5.5.3.3 Efficiency - The characteristic curve for pump efficiency is a plot of efficiency in percent versus pump discharge flow in gallons per minute. By following the path and slope of the efficiency curve through the range of discharge flows to be produced it is possible to interpret the various conditions that could be served by the pump with a particular impeller. In general, centrifugal pumps maintain high efficiencies over a rather narrow output range. It is not wise to select a pump on the basis of very high efficiency at a single design or specification point. Rather the selection should be made on the best average efficiency over the entire range of conditions under which the pump will operate including parallel operation with other pump units.

5.5.3.4 Power Input - The water horsepower of a pump is the rate at which energy is required to be supplied to the water by the pump. Specifically it is the number of pounds of water pumped per minute times the total head in feet divided by 33,000 (1 hp = 33,000 foot pounds per minute). The mechanical efficiency of a pump is the ratio of the water horsepower to the horsepower required to drive the pump. Brake horsepower is the actual horsepower required to be applied to the pump shaft to drive the pump, and is determined by dividing the water horsepower by the mechanical efficiency. The overall efficiency of a pumping installation (wire-to-water) is the water horsepower divided by the horsepower applied to the drive motor. Horsepower can be converted to kilowatts by multiplying by 0.746. Also see Sections 5.2.3.7 and 5.2.3.8.

5.5.3.5 Speed - Pumps are usually designed to operate at full load motor speeds. For 60 cycle operation these speeds are about: 695, 870, 1160, 1750, and 3500 rpm. The efficiency of squirrel cage type motors are 1/2 to 1 1/2 percent more efficient at 1160 and 1750 rpm than at higher or lower speeds, as a general rule.

In order to develop high heads, the peripheral speed of the impeller must be high. This can be obtained by: increasing impeller speed; increasing impeller diameter; or by adding pump stages. Higher speed is the least expensive way to produce higher heads with respect to initial cost, but this must be balanced against higher maintenance and shortened pump life which are associated with higher speed operation.

The desirability of using variable speed drives to meet widely varying head-capacity loadings has been mentioned previously.

The specific speed should be selected so as not to exceed that which the pump type can handle. The design specific speed of an impeller is an index as to its type. It is used when designing impellers to meet different conditions of head, capacity, and speed. Impellers for high heads generally have low specific speeds and impellers for low heads usually have high specific speeds. For a given head-capacity a pump of low speed and low specific speed will operate safely with a greater suction lift than one of a higher speed. When the suction lift is low or there is a positive head on the suction, speed may be increased and a smaller, cheaper pump used. Increased speeds without proper suction conditions can cause serious problems with vibration, noise, and pitting of pumps. There are upper limits of specific speed in respect to capacity, speed, head, and suction lift which should not be exceeded in order to avoid cavitation problems.

Positive suction head is recommended for centrifugal pump installations.

5.5.3.6 Space Requirements - In planning pump stations sufficient floor space should be provided for pumps, suction and discharge pipe headers, electrical switchgear, and for installation, removal, and servicing of pumps and auxiliaries. Access to pumps and motors and space for equipment needed to lift pumps should also be considered.

5.5.3.7 Operating Flexibility - Several types of starters may be used with pumping equipment:

a. Manual, full voltage

b. Magnetic, full voltage (across-the-line)
    1. push-button operated
    2. selector switch operated

c. Manual, reduced voltage

d. Magnetic, reduced voltage
    1. push-button operated
    2. selector switch operated

e. Combination, magnetic full-voltage, with
    1. fused switch
    2. non-fused switch
    3. circuit breaker switch

Arrangments to prime pumps are necessary when suction lift prevails. Centrifugal pumps may be provided with an air, steam, or water-operated ejector connected to the top of the pump case. The suction piping should be as short and direct as possible and of such a diameter that the volocity is less than 4 feet per second. The suction pipe should be larger than the discharge pipe. Pipe bends which unevenly distribute flow across the pump suction should not be used. Suction piping should slope upward from the source to the pump. Suction piping should be air-tight.

5.6.0 Automatic and Remote Controlled Stations(III-20)

All automatic stations should be provided with automatic signaling apparatus which will report when the station is out of service. All remote controlled stations should be electrically operated and controlled and have signaling apparatus of proven performance. Installation of electrical equipment should conform with the National Electrical Code.

5.7.0 Appurtenances(III-20)

5.7.1 Valves - Pumps should be adequately valved to permit satisfactory operation, maintenance, removal, and repair of the equipment. If foot valves are necessary they should have a net valve area of at least 2 1/2 times the area of the suction pipe, and they should be screened. Each pump should have a positive acting check valve on the discharge side between the pump and shutoff valve.

5.7.2 Piping - In general piping should:

a. be designed so that the friction head will be low;

b. not be subject to contamination;

c. be sloped in one direction to drains;

d. have adequate cleanouts;

e. have watertight joints;

f. be protected against surge or water hammer by:

   1. slow valve closure

   2. surge tank with free water surface

   3. air chamber

   4. surge suppressor

   5. surge relief valve

   6. pump reversal

g. be such that each pump has an individual suction line or the lines should be so manifolded that they will insure similar hydraulic and operation conditions;

h. be arranged for minimum interruption of service due to any one piping break. Where fire demand water is furnished, arrange to supply fifty percent of demand with a break in piping.

5.7.3 Gauges and Meters - Each pump should:

a. have a standard pressure gauge on its discharge line;

b. have a compound gauge on its suction line;

c. have recording gauges in large stations;

d. be such that each pump should have means for measuring the discharge.

The station should have indicating, totalizing and recording metering of the total water pumped.

5.7.4 Water Seals - Water seals should not be supplied with water of a lesser sanitary quality than that of the water being pumped. Where pumps are sealed with potable water and are pumping water of lesser sanitary quality, the seal should:

a. be provided with a break tank open to atmospheric pressure;

b. have an air gap between feeder line and spill line of the tank, at least 15 cm (6 inches) or two pipe diameters, whichever is greater.

5.7.5 Controls - Pumps, their prime movers and accessories, should be controlled in such a manner that they will operate at rated capacity without dangerous overload. Where two or more pumps are installed, provision should be made for proper alternation. Provision should be made to prevent operation of the pump during the backspin cycle. Electrical controls should be located above grade.

5.7.6 Power - When power failure would result in cessation of minimum essential service as specified in Sections 1.3.0 and 1.5.0, power supply should be provided from at least two independent sources or standby or auxiliary source should be provided.

5.7.7 Auxiliary Power Supply - When automatic pre-lubrication of pump bearings is necessary, and an auxiliary power supply is provided, the pre-lubrication line should be provided with a valved by-pass around the automatic control.

SECTION V PUMPING FACILITIES

RATIONALE FOR PUMPING FACILITY STANDARDS

5.1.0 General

Pumps are often installed at central points from which water is distributed to large numbers of people, so that it is important that they be selected, located, protected, installed, equipped, operated, serviced, maintained, and repaired so as to preserve the sanitary quality of the water being pumped. This can be facilitated by designing pumping stations for ease of operation and maintenance. The standing or pooling of flood or other contaminated waters around pumps, piping, and auxiliaries is particularly hazardous. Under certain conditions such water may enter faulty well seals, vents, pipe joints, or pump connections with contamination of the water supply. For these reasons, sub-surface pits and inaccessible installations should be avoided.

5.1.1 Location

The requirements for location of pumping stations are intended: to allow an efficient hydraulic arrangement; to prevent water quality deterioration; to avoid interruption of service by natural disasters and man's activities; to insure access and availability of utility services; and to permit future expansion of the station.

5.2.0 Ground Water Facilities

5.2.1 Sanitary Protection

The precautions prescribed here are taken primarily from existing State Standards which are based on the experience of operating hundreds of existing wells.

5.2.2 Well Construction

This item has been covered under Section 2.4 of this Manual. For supplemental information reference is made to Chapter 4 of AWWA Manual No. M21, "Ground Water".

5.2.3 Well Pumps

5.2.3.1 Certified Pumps

The AWWA Standard No. E101 - 71, "American National

Standard for Deep Well Vertical Turbine Pumps - Line Shaft and Submersible Types" was developed by the AWWA under the procedures of the American National Standards Institute. Appendix A, "Field Testing of Deep Well Turbine Pumps" was developed by AWWA to supplement the shop testing requirements provided by the standard.

Although the standard describes equipment to be used in the prime production of water from deep wells, it also can be utilized for obtaining pumps for other purposes, subject to modification for certain uses based on consultation with the manufacturer. Part A of the Standard provides minimum requirements for line shaft vertical turbine pumps with discharge column pipe up to and including 40 cm (16 inches) diameter. Part B of the Standard provides minimum requirements for submersible vertical turbine pumps utilizing a 7.6 metric hp (7 1/2 hp) motor or larger. Appendix A gives information on field testing of deep well turbine pumps including the purpose, the limits of accuracy, definitions and symbols, approved instrumentation, and procedures.

5.2.3.2 Desirable Operating Conditions

The Standards of this Section are aimed at maintaining pumping equipment in service and at avoiding interruptions in water service.

5.2.3.3 Drives

If there are situations where use of the Standards in sizing pump drive units to meet unusual operating conditions imposes an unnecessary economic burden on the installation, the water utility may submit alternate means for protecting pumping equipment for consideration of the State.

5.2.3.4 Power Requirements

A dependable source of power is essential. Where power shutdowns can occur, an independent reliable emergency source of power should be available of sufficient size to provide the required supply of water.

5.2.3.5 Pump Selection and Installation

As given in the Standards, factors to be considered in selecting a pump for a particular well installation include: (1) capacity, (2) depth of well and pumping level, (3) inside diameter of well, (4) condition of bore, whether straight or crooked, (5) abrassive quality of water (amount of sand present), (6) total head, (7) type of power available, and (8) costs. The choice among types of pumps meeting physical and hydraulic requirements usually rests with economics. Costs for construction and operation over the service life of the installation should be minimal.

Operational limits of ordinary pumping units have been stated in the Standards. Note that the single-stage centrifugal-type pump offers satisfactory and economical service. Sizes are available for practically any desired capacity, but application is restricted because the suction lift must be not more than about 6.7 meters (22 feet), depending upon elevation and temperature.

If a well is clean and free of sand or grit, a rotary type of pump may perform as satisfactorily as a centrifugal pump, but rotary units are applicable only for operations that present low rates of flow. Suction-lift specifications for rotary types of pumps are the same as for centrifugal types.

A centrifugal and jet, or ejector, combination pump can be used to produce low rates of flow and suction lifts to 36 meters (120 feet). On deeper wells, jets sometimes are used in combination with positive-displacement pumps.

If large capacity is desired and the lift is more than 36 meters (120 feet), the vertical deep-well turbine probably would be the best selection, but for small capacity deep-well operations the plunger type of pump has proved satisfactory.

For all but positive-displacement pumps, the discharge head increases as the rate of flow or capacity decreases, and the discharge head decreases as the rate of flow or capacity increases; therefore, if constant discharge under a varying head is to be maintained by a centrifugal pump, a variable-speed drive must be used. No problem is encountered when a positive-displacement pump is used because the capacity depends on the speed of the pump. The pressure that can be developed by a plunger-type pump is limited only by the size of the power unit and strength of materials.

After a well has been tested for yield, the requirements placed on it are dictated by demand. For some wells, it is advisable to keep a constant drawdown to prevent production of sudden changes in water quality or sand.

If a well is too crooked for efficient operation of a deep-well turbine and use of a plunger-type pump is not desirable, it could be more economical in the long run to install a submersible pump, even though initial installation might be more expensive.

A chemical analysis should be run on the water to be pumped. A pump built with special materials may be needed to keep corrosion cost at a minimum.

Total head must be determined because it may be necessary not only to lift or push the water to ground-surface elevation, but also to pump this water to storage or to the consumer. Sufficient head needed to perform both tasks determines the motivating horsepower required.

Available power must be considered because the type of pump selected should be adaptable to operate from the cheapest power source available at an installation.

The overall efficiency of a pump system depends on many factors, such as specific speed, relative size, service, materials, and physical characteristics of fluid. Large centrifugal pumps have developed over 92 percent efficiency, whereas the efficiency of smaller pumps may in some instances by only from 20 to 25 percent.

To determine the overall efficiency of a pumping system, consider the efficiency of the pump, prime mover, and drive.

In general, pumps are driven by direct connection to prime movers through use of right-angle drives or belts. Electric motors and gasoline or diesel engines usually are used as prime movers for water-well pumps.

After all system characteristics are determined, the type of pump that offers suitable capacity to perform the work efficiently is selected. Before a final choice is made, the pump specifications comparison curve for various types of pumps offered by different manufacturers must be studied.

Selection should not be determined on efficiency or price alone. Investigate all of the preceding factors and try to transfer them to installation and maintenance costs based on the term of anticipated use. The most economical installation is not necessarily the one with the lowest initial pump cost.

Previous to pump selection, the pumping level should have been determined to assure that the pumping element will be placed below the maximum drawdown.

The well must be deep enough and of ample size to receive the pump and sufficiently straight to allow proper operation.

The pump should be placed so that it is easily accessible for regular inspection during operation. Ample room should be provided for use of a crane, hoist, or tackle. The pump should be placed on a good foundation, preferably made of concrete. Foundation bolts should be placed according to dimensions usually furnished by pump manufacturers.

Pumps should be properly aligned by leveling the base and by bringing the pump and driving unit into exact alignment with shims. Experience has proved that nearly all bases, no matter how rugged, will spring and twist to some degree during shipment. Consequently, it is necessary that the alignment be given considerable attention when the unit is being installed.

Piping should line up naturally, and not be forced into place with flange bolts, and should be supported independently of the pump to eliminate strain on the pump casing. After the piping has been installed, alignment should be rechecked. On unusually long discharge lines, a packed slip joint should be installed to compensate for elongation of pipe that might result from pressure or temperature changes.

To protect the pump, one should install a flexible coupling, a gate valve, and check valve in the discharge pipe close to the pump. The check valve should be placed between the pump and a gate valve. If pipe connections are used on the discharge end of the pump to increase the size of discharge piping, they should be placed between a check valve and the pump. The selection of the discharge piping should be made with due reference to expected friction losses.

Check alignment after the piping has been completed, using a straight edge and thickness gauge. When pumping units have been aligned before piping is completed, piping strains that develop are probably the cause of any misalignments. Changes should be made accordingly. If stuffing boxes are adjusted properly and the pump and drives are aligned properly, the unit can usually be operated by hand with ease.

The manufacturer's installation check list and adjustment directions should be closely followed and double checked before applying power to the pump unit.

Contamination often enters a well at the ground surface through the well bore; hence it is important to seal any space between the casing and the pump pipe. Such space should be tightly sealed by an approved sanitary well seal. Watertight covers, preferably of impervious concrete, should be used, and the casing should be extended at least 0.3 meters (1 foot) above the surface.

Surface pollution may also enter a well through space between the outside of the casing and the wall of the well bore. This space, therefore, should be sealed securely by proper grouting; then a concrete platform should be constructed around the well.

5.3.0 Surface Water Facilities

The Standards set forth in this Section of the Manual are to be applied with conservative judgement, in accordance with the purpose, scope, and limiting design factors which prevail for a particular installation. Pumps may handle raw, semi-finished, or potable water under low, intermediate, or high lift, or in booster service with manual, automatic, or remote controls. Pumping stations may function as individual units, as treatment plant units, main pumping stations, or for combined services. Details of design obviously must be tailored to suit these widely variable conditions of function and service.

5.3.1 Suction Well

The Standards for construction of suction wells serve to protect water against introduction of foreign materials.

5.3.2 Equipment Servicing

The stipulations here are to facilitate operation and maintenance so that pumping stations will function as intended.

5.3.3 Stairways and Ladders

Unless properly installed, stairs and ladders can be safety hazards.

5.3.4 Heating

Attended stations should be heated for the comfort of the operator, and unattended stations should have sufficient heat to protect equipment against freezing.

5.3.5 Ventilation

Adequate ventilation is required for safety, to prevent damage to equipment, and for the comfort of operators.

5.3.6 Dehumidification

Often there are areas in water pumping stations which tend to produce or hold moisture which may accelerate corrosion of electrical or other equipment, and in these situations the need for dehumidification should not be overlooked.

5.3.7 Lighting

Adequate lighting is basic to safety as recognized by all State and Local building codes.

5.3.8 Sanitary and Other Conveniences

These facilities are required for the comfort and convenience of operators and visitors, and for protection of the water supply.

5.3.9 Pumps

The requirements for standby pump capacity are made to assure uninterrupted water service and maintenance of adequate pressures in water distribution systems which protect against contamination of potable water through back-siphonage and cross-connection.

5.3.10 and 5.3.11 Suction Lift and Priming

The Standards here are precautions against contamination hazards which can exist when priming pumps or in operating under excessive suction lift. When a leak occurs in a submerged suction pipe, water from outside may be drawn in if the pump is operating, or flow in by gravity at other times. This requires protection of suction piping.

5.4.0 Booster Pumps

These pumps should be installed and equipped to maintain the minimum suction pressures needed to provide protection against contamination of the water being pumped.

5.5.0 Selection of Pumps for Surface Water Facilities and Booster Service

Pumping stations should be capable of furnishing the peak demands plus fire requirements with the largest pumping out of service. If there is more than one pumping station, or if the demands can be met from more than one point by wells or from storage, system reliability is increased and the needs for standby service may be somewhat reduced. In addition to the reliability of pumps, consideration should be given to the reliability of power supply, equipment, and piping.

5.6.0 Automatic and Remote Controlled Stations

Alarm panels to signal equipment malfunctions are essential for satisfactory operation of unattended pumping stations.

5.7.0 Appurtenances

The pump appurtenances required by the Standards represent minimum facilities for satisfactory station operation based on extensive operating experience with existing installations.

SECTION VI STORAGE

SUMMARY OF STANDARDS FOR FINISHED WATER STORAGE

6.0.0 General (III-20) (VI-4)

The materials and designs used for finished water storage structures should provide stability and durability as well as protect the quality of the stored water. Steel Structures should conform to, AWWA D100 73, "AWWA Standard for Welded Steel Elevated Tanks, Standpipes, Reservoirs, and Elevated Tanks for Water Storage". Concrete and other materials of construction are acceptable when properly designed to meet the requirements of this section. See Section II for consideration of source water storage.

6.1.0 Selection of Type and Location of Storage

6.1.1 Type

a. The three types of finished water storage are classified with respect to their elevation as compared to that of the ground:

   1. elevated

   2. ground level

   3. underground

b. Selection of Type. The selection of the type or types of storage to be provided depends on several considerations:

   1. aviation hazards

   2. economics - large storage requirements may favor ground level or underground tanks. The existance of a hill in the right spot and at the right elevation may provide elevated storage at the cost of ground level reservoirs.

   3. freezing problems

   4. topography and hydraulic grade lines

   5. sabatoge potential or other need for concealment underground

6.1.2 Location

a. The bottom of ground level reservoirs and standpipes should be placed at the normal ground surface and above the 100 year flood level.

b. Where the bottom must be below normal ground surface, it should be placed above the ground water table. Sewers, drains, standing water, and similar sources of contamination should be kept at least 15 meters (50 feet) from the reservoir. Mechanical-joint water pipe, pressure tested in place to 3.5 Kg/Sq. cm (50 psi) without leakage, may be used for gravity sewers at lesser separations.

c. The top of a ground-level reservoir should not be less than 0.6 meters (2 feet) above normal ground surface and any possible flood level. Reservoirs may be expected from this requirement when the total design gives the same protection.

d. Location for finished water storage should be selected in consideration of the centers of water demand for large and small distribution systems.

6.2.0 Protection (III-20) (VI-4)

6.2.1 Covers and Roofs

All finished water storage structures should have suitable watertight roofs or covers which exclude birds, animals, insects, and excessive dust.

6.2.2 Protection From Trespassers

Fencing, locks on access manholes, and other necessary precautions should be provided to deter trespassing, vandalism, and sabotage.

6.2.3 Drains

No drain on a water storage structure should have a direct connection to a sewer or storm drain.

6.2.4 Overflow

The overflow pipe of a water storage structure should be brought down near the ground surface and discharged over a drainage inlet structure or a splash plate. No overflow should be connected directly to a sewer or storm drain.

a. When an internal overflow pipe is used, it should be located in the access tube.

b. The overflow of a ground-level structure should be high enough above normal or graded ground surface to prevent the entrance of surface water.

c. Overflow capacity should equal maximum inlet flow.

6.2.5 Access

Finished water storage structures should be designed with reasonably convenient access to the interior for cleaning, maintenance, and sampling. Also see Surveillance Section IX. Manholes on scuttles above waterline should:

a. be framed at least 10 cm (4 inches), and preferably 15 cm (6 inches), above the surface of the roof at the opening; on ground-level structures manholes should be elevated 0.6 to 0.9 meters (24 to 36 inches) above the top or covering sod;

b. be fitted with a solid watertight cover which overlaps the framed opening and extends down around the frame at least 5 cm (2 inches);

c. be hinged at one side;

d. have a locking device.

6.2.6 Vents

Finished water storage structures should be vented by special vent structures. Open construction between the sidewall and roof is not recommended. These vents should:

a. prevent the entrance of surface water;

b. exclude birds and animals;

c. exclude insects, rain, and dust by vent cap or other means as much as this function can be made compatible with effective venting; for elevated tanks and standpipes, eight-mesh noncorrodible screen may be used;

d. on ground-level structures, terminate in an inverted U construction, the opening of which is 0.6 to 0.9 meters (24 to 36 inches) above the roof or sod and is covered with twenty-four mesh noncorrodible screen cloth.

6.2.7 Roof and Sidewall

The roof and sidewalls of all structures should be watertight with no openings except properly constructed vents, manholes, overflows, risers, drains, pump mountings, control ports, or piping for inflow and outflow.

a. Any pipes running through the roof or sidewall of a finished water storage structure should be welded or properly gasketed in metal tanks, or connected to standard wall castings which are poured in place during the forming of a concrete structure; these wall castings should have flanges imbedded in the concrete.

b. Openings in a storage structure roof or top, designed to accommodate control apparatus or pump columns, should be curbed and sleeved with proper additional shielding to prevent the access of surface or slop water to the structure.

c. Valves and controls should be located outside the storage structure so that valve stems and similar projections will not pass through the roof or top of the reservoir and will not be subject to contamination by surface water.

6.2.8 Drainage for Roof or Cover

The roof or cover of the storage structure should be well drained, but downspout pipes shall not enter or pass through the reservoir; parapets, or similar construction which would tend to hold water and snow on the roof are not recommended.

6.2.9 Safety

The safety of employees should be considered in the design of the storage structure. As a minimum, such matters should conform to pertinent laws and regulations of the area where the reservoir is constructed.

a. Ladders, ladder guards, balcony railings, and safe location of entrance hatches should be provided where applicable.

b. Elevated tanks with riser pipes over 20 cm (8 inches) in diameter should have protective bars over the riser openings inside the tank.

6.2.10 Freezing

All finished water storage structures and their appurtenances, especially the riser pipes, overflows, and vents should be designed to prevent freezing which will interfere with proper functioning. Consideration should be given to heating and/or insulation on exposed pipes and valves.

6.2.11 Internal Catwalk

Every catwalk over finished water in a storage structure should have a solid floor with raised edges so designed that shoe scrapings and dirt will not fall into the water.

6.2.12 Grading

The area surrounding a ground-level structure should be graded in a manner that will prevent surface water from standing within 15 meters (50 feet) of the structure.

6.2.13 Painting and/or Cathodic Protection

Proper protection should be given to metal surfaces by paints or other protective coatings, by cathodic protective devices, or by both. Paint systems consistent with AWWA Standard D102 - 64, or otherwise acceptable to the State, should be used.

a. Cathodic protection should be designed, installed, and maintained by competent technical personnel.

b. Provide proper painting and lighting for aircraft visibility.

6.2.14 Silt Protection

Discharge pipes should be located to prevent silt from entering the distribution system. Silt stops are recommended where required.

6.2.15 Fire Protection

Elevated storage should have adequate clearance from buildings or other combustibles, or consider fire-proofing legs.

6.3.0 Materials(III-20) (VI-4) (VI-1) (VI-3)

6.3.1 Steel

Steel water tanks should conform to AWWA Standard D100 - 73.

6.3.2 Concrete

Current design and construction practices for prestressed concrete storage tanks is summarized by R.D. Woodside in the May, 1972 (p. 289) J AWWA, and maintenance and repair of concrete reservoirs is discussed in articles by F.E. Harem in the September, 1964 (p. 1160) J AWWA, and by C.G. Walters, in the May, 1965 (p. 596 J AWWA. These designs and construction practices should be followed wherever possible.

6.4.0 Disinfection(VI-3)

Finished water storage structures should be disinfected before being put into service after inspection, or following repair. The detailed procedures to be followed, equivalent to those outlined in the current American Water Works Association Standard D102 for painting and repairing steel tanks, standpipes, reservoirs, and elevated tanks, should be written into the specifications by the designing engineer.

a. Two or more successive sets of samples taken at 24-hour intervals, shall indicate bacteriologically satisfactory water before the facility is released for use. See Surveillance Section IX.

b. Provide smooth end taps in riser pipes and connecting mains where disinfectant is added.

6.5.0 Plant Storage(III-20)

The applicable design standards of this Section should be followed for plant storage reservoirs.

6.5.1 Washwater Tanks

Washwater tanks should be sized, in conjunction with available pump units and finished water storage, to give the backwash water required by Section 3.2.1.10.

a. Consideration should be given to the possibility of having to wash more than one filter at a time, or several filters in succession.

6.5.2 Clearwell

Clearwell storage should be sized, in conjunction with distribution system storage, to relieve the filters from having to meet all fluctuations in water use or meet peak demands, including use of filter backwash water and loss of capacity due to filter outages.

a. When finished water storage is used to provide proper contact time for disinfection (see 3.3) special attention should be given to size and baffling.

6.5.3 Adjacent Compartments

Finished water should not be stored or conveyed in a compartment adjacent to unsafe water when the two compartments are separated by a single wall.

6.5.4 Basins and Wet-Wells

Receiving basins and pump wet-wells for finished water should be designed as finished water storage structures.

6.5.5 Pressure Tanks

Hydropneumatic (pressure) tanks may be acceptable in some small water systems. When used, they should meet ASME Code requirements for unfired pressure vessels, and should comply with the requirements of state and local laws and regulations for such construction.

a. The tank should be located above normal ground surface and be completely housed, or earth-mounded with one end projecting into an operating house, to prevent freezing.

b. The tank should have bypass piping or a duplicate unit to permit operation of the system while the tank is being repaired or painted.

c. Each tank should have an access manhole, a drain, and control equipment consisting of pressure gauge, water sight glass, automatic or manual air blow-off, mechanical means for adding air, and pressure-operated start-stop controls for the pumps.

d. The total capacity of the wells and pumps in a hydropneumatic system should be at least six to ten times the average daily consumption rate of the community. A minimum of two wells or pumps should be provided.

e. The gross volume of the hydropneumatic tank, in gallons, should be at least ten to fifteen times the capacity of the largest pump, rated in gallons per minute. For example, a 946 Lpm (250 gpm) pump should have a minimum 9,500 to 14,200 liter (2,500 to 3,750 gallon) pressure tank.

6.6.0 Distribution Storage(III-20) (VI-4)

The applicable design standards of this Section should be followed for distribution storage.

6.6.1 Capacity

As a minimum, distribution system storage capacity should be sufficient to take care of hourly variations in water demands and pressures during the day plus the required reserve for fire protection and minor contingencies. For the required fire reserve see, "Guide for Determination of Required Fire Flow", of the Insurance Services Office (formerly National Board of Fire Underwriter's), 160 Water Street, New York, New York 10038. Storage in the distribution system should be capably of replenishment each night during low-demand periods.

6.6.2 Pressure Variation

The maximum variation between high and low levels in storage structures which float on a distribution system should not exceed 9 meters (30 feet).

6.6.3 Drainage

Storage structures which float on the distribution system should be designed to drain for cleaning or maintenance without necessitating loss of pressure in the distribution system. The drains should discharge to the ground surface with no direct connection to a sewer or storm drain.

6.6.4 Level Controls

Adequate controls should be provided to maintain levels in distribution system storage structures.

a. Telemetering equipment should be used for storage structures when pressure-type controls are employed in control stations and any appreciable head loss occurs in the distribution system between the source and the storage structure.

b. Altitude valves or equivalent controls may be desirable for a second and subsequent structure on the system. Set high water level one meter (3 feet) below overflow to prevent tank roof damage from floating ice.

c. Overflow and low-level warnings or alarms should be located at places in the community where they will be under responsible surveillance on a 24-hour basis.

6.6.5 Miscellaneous Design Considerations

a. Provide for water circulation through reservoirs by the use of baffles, or by placing inlets and outlets on opposite sides of the reservoir with outlets near the bottom.

b. Valve all pipes except overflow.

c. Minimum reservoir water depth should be 4 meters (12 feet).

d. Provide more than one reservoir to provide storage during outages, or, in the case of a single reservoir, divide into compartments so at least one section is available for use at all times.

e. Reservoirs should be drained and cleaned at intervals not greater than every two years.

RATIONALE FOR STORAGE STANDARDS

6.0.0 General

Storage is an essential element of any water system. The principal function of distribution storage is to make it possible to process the water at times when facilities would otherwise be idle and to distribute and store it in advance of its actual need at one or more locations in the service area close to the users. Storage makes it possible to more nearly equalize the demands on the sources of supply, the production works, the transmission and distribution mains, thus, the sizes and capacities of these elements of the system need not be so great as in the absence of storage. System flows and pressures are improved and stabilized better to serve the customers throughout the service area. Further, reserve supplies are provided in the distribution system for contingencies such as fire fighting and power outages. Distribution storage serves two principal purposes, water is stored to meet variations in system demand and outages, and it is stored to provide water for fire protection in the event of a failure of plant facilities. Storage requirements for these two opposing functions should be considered separately and combined in computing the total amount of storage that must be provided.

6.1.0 Selection of Type and Location of Storage

6.1.1 Type

The selection of type of storage (elevated, ground, underground) depends of topography; aviation hazards; economics; freezing problems; and sabatoge potential.

6.1.2 Location

The location, capacity, and elevation of distribution storage are closely associated with water demands and their variation throughout the day in different parts of the system. Normally, it is advantageous to provide several smaller units in different parts of the system than to provide the same capacity at a single central location.

Smaller pipelines are required to serve decentralized storage, and a lower pumping head results.

Normally, some water should be withdrawn from storage each

Preceding page blank

day. This maintains continuity in the output of production and pumping works and provides circulation of the stored water.

The quantity of water in storage and its elevation and location should be properly related to the maximum demands in different parts of the system. These are local variables which can be determined only after a careful analysis and study of a particular system. There are some general rules, however, that may serve as a guide to individual analysis. The provision of usable storage in the amount of 10 to 15 percent of the average daily water demand will level out the peaks and permit a fairly uniform production rate. In systems of moderate size, the amount of storage which is usable for flow equalization is about 30 to 40 percent of the total storage available for both flow equalization and contingency reserve. In other words, the storage for contingency reserve would be about 2.5 to 3 times that for flow equalization in moderate size service areas.

6.2.0 Protection

6.2.1 Covers and Roofs

To protect the stored water against chance contamination and quality deterioration all finished water reservoirs containing water for potable use should be covered.

Stored, treated water in the distribution system may be contaminated by substances that fall into uncovered finished water storage tanks or reservoirs, by wind-blown material entering vents, and by ground or surface water seepage. Open storage is subject to pollution from gulls, ducks, and other birds; animals, such as rodents; wind-blown contaminants; human activities such as bathing, fishing, and deliberate contamination; and many other sources. The best method to prevent deterioration of the quality of water stored in tanks and reservoirs is to provide water-tight storage facilities that are constructed with roofs to afford protection against surface runoff. In the absence of such cover, disinfection of all water fed to the system from storage is essential and tends to offset, but does not prevent, the ill effects from this introduced contamination.

6.2.2 Through 6.2.12

These detailed requirements for protection of water quality in reservoirs have been arrived at principally by experience in the operation of storage reservoirs over many years.

6.2.13 Painting and/or Cathodic Protection

The AWWA Standards for painting exclude the use of paints which might add toxic materials to the stored water through leaching or other action. Cathodic protection devices must be regularly inspected and maintained for satisfactory performance.

6.2.14 Silt Protection

Reservoirs should be protected against entry of silt through discharge pipes.

6.2.15 Fire Protection

Elevated steel tanks should be protected against damage of structure failure from fire in the vicinity of the tanks.

6.3.0 Materials

Steel and concrete are permitted by the Standards. Other suitable materials may be approved at the discretion of the State.

6.4.0 Disinfection

New reservoirs and reservoirs which have been emptied for service or repair should be disinfected to insure that any contamination introduced by workmen or materials during the course of construction or maintenance which has not been physically removed by cleaning the floor, walls, and pipelines of the reservoir is rendered harmless to water users.

6.5.0 Plant Storage

Water storage may be provided at the treatment plant for in-plant uses (the principal in-plant use being for filter backwashing) or to reduce the total amount of distribution system storage required for flow equalization from the treatment plant.

6.5.1 Washwater Tanks

The capacity in storage required for this in-plant use, as given by Section 3.2.1.10, is the quantity of water required to backwash a filter for 15 minutes at the design backwash flow rate. However, consideration should be given to the possible need to wash more than one filter at a time, or several filters in succession.

6.5.2 Clearwell

Clearwells should be sized in conjunction with distribution system storage to meet the needs of peak flows plus filter backwash.

6.5.3 Adjacent Compartments

This recommendation is necessitated by the possible leakage of unsafe water into potable water storage through cracks or leaks in the division wall.

6.5.4 Basin and Wet-Wells

These structures contain finished water and should meet the requirements for such structures.

6.5.5 Pressure Tanks

The requirements here have been derived empirically for the most part, based on operating experience over many years.

6.6.0 Distribution Storage

The requirements for distribution storage reservoirs are based on the need to maintain adequate quantities and pressures of water in the distribution system in order to protect the sanitary quality of the water for use of consumers.

6.6.5 Miscellaneous Design Considerations

Circulation of water through reservoirs can assist in the control of tastes and odors, maintenance of residual disinfectant, and control of slime growths. Reservoirs should be cleaned periodically to prevent accumulation of sediments and the creation of chlorine-demanding residues.

SUMMARY OF STANDARDS FOR DISTRIBUTION SYSTEMS

7.1.0 General Protection Principles (III-20)(VII-3)(VII-27)

7.1.1 Quantity and Pressure

Water distribution systems should be designed, constructed, and operated to provide, at all times, an adequate supply of water at ample pressure, not less than 1.4 Kg/Sq. cm (20 psi), in all parts of the system. See Sections 1.2.3, and 2.2.0 for capacity considerations and Section 1.3.0 for siting considerations.

7.1.2 Quality

The safety and palatability of potable water should not be degraded in any manner while flowing through the distribution system.

7.1.3 Quality Sampling

Water samples for chemical and bacteriological analysis should be collected from representative points on the distribution system, and the location of these points evaluated frequently to assure that the samples collected actually properly represent the quality of water being delivered to consumers. See Section IX for Surveillance Considerations.

If necessary to secure representative samples from all parts of the distribution system, install special smooth nose sampling taps on the distribution with due consideration in selecting locations to potential problems of freezing, breakage, vandalism, and access.

7.1.4 Valves

The system should be provided with sufficient isolation and drain valves to permit necessary repairs without undue interruption of service over any appreciable area. Blow-off connections to sewers or sewer manholes are not recommended.

7.1.5 Disinfection

All water should be properly disinfected before it reaches the first (nearest) consumer on the distribution system. Water stored for prolonged periods in reservoirs may require redisinfection upon reentry to the system.

7.1.6 Cross-Connections

Physical cross-connections that allow unsafe water to enter the distribution system are not recommended. See EPA "Cross-Connection Control Manual, 1974".

7.1.7 Leakage

The system should not have leakage in excess of 10 per cent.

7.1.8 Submarine Lines

Special precautions should be taken to prevent possible damage to submarine lines. See 7.2.2.6.

7.1.9 Repairs, Replacements and Extension of Mains

The system should be maintained so as to prevent contamination of any part of the system during necessary repairs, replacements, or extensions of mains. When pressure in any part of the distribution system becomes abnormally low, customers in the area should be notified of necessary protective health precautions.

7.2.0 Pipeline Location and Protection (III-20)(VII-3)(VII-27)

7.2.1 Location

7.2.1.0 General Location Considerations

a. See Section 1.3.0.

b. Use available data on topography, soil, geology, and climate.

c. Tunneling should be considered only when it is economically justified and when there are no feasible alternate routes.

d. Use gravity lines wherever possible.

e. Select shortest route from intake to delivery.

f. Make lines accessible for future construction and repairs.

g. Avoid rough or difficult terrain.

h. Avoid areas where disasters such as landslides, 100-year floods, or other hazards are likely to cause breakage or outage.

7.2.1.1 Separation of Water Mains and Sewers

General - The following factors should be considered in providing adequate separation:

a. materials and type of joints for water and sewer pipes;

b. soil conditions;

c. service and branch connections into the water main and sewer line;

d. compensating variations in the horizontal and vertical separations;

e. space for repair and alterations of water and sewer pipes;

f. off-setting of pipes around manholes.

Parallel Installation:

Normal conditions - Water mains should be laid at least 3 meters (10 feet) horizontally from any sanitary sewer, storm sewer or sewer manhole, whenever possible; the distance should be measured edge-to-edge.

Unusual conditions - When local conditions prevent a horizontal separation of 3 meters (10 feet), a water main may be laid closer to a storm or sanitary sewer provided that:

a. the bottom of the water main is at least 45 cm. (18 inches) above the top of the sewer;

b. where this vertical separation cannot be obtained, the sewer should be constructed of materials and with joints that are equivalent to water main standards of construction and be pressure tested to assure watertightness prior to backfilling.

Crossings:

Normal conditions - Water mains crossing house sewers, storm sewers or sanitary sewers should be laid to provide a separation of at least 45 cm (18 inches) between the bottom of the water main and the top of the sewer, whenever possible.

Unusual conditions - When local conditions prevent a vertical separation as described above, the following construction should be used:

a. Sewers passing over or under water mains should be constructed of the materials equivalent to water main standards of construction and be pressure tested to assure water-tightness prior to backfilling.

b. Water mains passing under sewers should, in addition, be protected by providing:

   1. a vertical separation of at least 45 cm (18 inches) between the bottom of the sewer and the top of the water main;

   2. adequate structural support for the sewers to prevent excessive deflection of joints and settling on and breaking the water mains;

   3. that the length of water pipe be centered at the point of crossing so that the joints will be equidistant and as far as possible from the sewer.

Sewer manholes - No water pipe should pass through or come into contact with any part of a sewer or sewer manhole.

7.2.1.2 Drains

Underground drains from fire hydrants and valves or valve pits should not be directly connected to sewers or storm drains.

7.2.1.3 Trench Flooding

Insofar as possible, water pipes should not be laid in water, or in trenches where they can be flooded with water or sewage during the laying process.

7.2.1.4 Frost

The top of all water pipes should be at least 15 cm (6 inches) below the maximum recorded depth of frost penetration in the area of installation. The minimum depth of water mains should be one meter (3 feet) from ground surface to top of pipe.

7.2.1.5 Dead Ends

Dead ends should be minimized by looping of all mains. Where dead-end mains occur they should be provided with a fire hydrant, flushing hydrant, or blow-off for flushing purposes.

Where dead-end lines are necessary in the first stage of construction of a pipe system, the pipe layout should be designed for future additions and connections to provide water circulation.

7.2.2 Protection

7.2.2.1 Pressure

The pipe system and its appurtenances should be designed to maintain an adequate positive water pressure 1.4 Kg/Sq. Cm. (20 psi) minimum throughout the system.

7.2.2.2 Caulking Materials

Materials used for caulking pipe joints should not be capable of supporting growth of pathogenic bacteria and shall be free from oil, tar, or greasy substances.

7.2.2.3 Lime Deposits

Corrective water treatment should be practiced where the lime or biological deposits in the mains tend to reduce the effective size and capacity of the pipes. To prevent and destroy biological deposits, heavy disinfection may be effective. Consumers should be informed of methods used and reasons corrective treatment should not violate Federal Drinking Water Standards.

7.2.2.4 Corrosion

The corrosive effects of finished water on non-ferrous metal pipe used for water service lines should be considered including possible toxicological effects upon consumers resulting from solution of the metals.

Water mains should be protected from exterior corrosion in cinder cuts or in corrosive soils by use of selected material for backfill and by wrapping or coating the pipe exterior with protective material.

7.2.2.5 Corrosion Control

Chemicals added to the water for corrosion control should conform to the applicable AWWA Standard and be acceptable to the State.

Material	AWWA Standard No.
Trisodium phosphate	B500-66
Caustic soda	B501-64
Sodium hexametaphosphate	B502-67

Consumers should be informed of methods used and reasons corrective treatment should not violate Federal Drinking Water Standards.

7.2.2.6 Surface Water Crossings

Surface water crossings, both over and under water, present special problems which should be discussed with the State before final plans are prepared. Where ground has inadequate bearing capacity use pile supports and stringers or other acceptable methods.

Above-water crossings - The pipe should be:

a. adequately supported;

b. protected from damage and freezing;

c. accessible for repair or replacement.

Underwater crossings -

a. The pipe should be of special construction, having flexible, watertight joints.

b. Valves should be provided at both ends of water crossings so that the section can be isolated for test or repair; the valves should be easily accessible and not subject to flooding.

c. Sampling taps should be available at each end of the crossing.

d. Permanent taps should be made for testing and locating leaks.

Railroad Crossings and Mains Near Tracks

Where a water main crosses under railroad tracks, all joints lying within 3 meters (10 feet) of the rails should be either mechanical joints with rubber gaskets or leaded bell-and-spigot joints with bell-joint clamps and rubber gaskets. Also local requirements should be investigated. Some railroads require that the water main be enclosed in a culvert, tunnel, or conduit to reduce the effects of vibration, to provide drainage in case of leakage or rupture of the pipe, to reduce damage to the track, and to facilitate repairs.

7.2.2.7 Plastic Pipe

Only nontoxic plastic pipe should be used, where plastic pipe is accepted by the State.

7.2.2.8 Sanitary Precautions

Sanitary precautions should be taken in laying new pipe, especially in preventing the introduction of foreign materials into the pipe.

7.2.2.9 Leakage

The amount of line leakage should be determined by hydropressure tests, and should not exceed the amount prescribed in AWWA C600, "Standard for Installation of Cast-Iron Water Mains".

7.2.2.10 Disinfection

New mains and repaired main sections should be adequately disinfected before being placed in or returned to service. The AWWA Standard for Disinfecting Water Mains, AWWA C601-68, should be the procedure used for these purposes. Avoid environmental damage when flushing mains and disposing of chlorinated water. Other methods used for disinfection should be approved by the State.

7.2.2.11 Bacteriological Examination

Before new lines and appurtenances are placed in service, the absence of pollution should be demonstrated by bacteriological sampling and examination. For number and frequency see Section IX.

7.2.2.12 Thrust Blocks

At all tees, bends, plugs, and hydrants provide adequate concrete thrust blocks or other backing to prevent pipeline movement.

7.3.0 Materials and Installation (III-20)(VII-3)

7.3.1 Distribution Systems

Materials and construction methods used in water distribution systems should conform to the applicable AWWA or American National Standard as listed below, or the latest revision and should be acceptable to the State.

Item	Standard No.
Cast-iron pipe thickness	ANSI A21.1-1967
Cement-mortar lining for cast-iron and ductile-iron pipe and fittings	ANSI A21.4-1971
Cast-iron pipe centrifugally cast in metal molds	ANSI A21.6-1970
Cast-iron pipe centrifugally cast in sand-lined molds	ANSI A21.8-1970
Gray-iron and ductile-iron fittings, 2 in. through 48 in.	ANSI A21.10-1971
Rubber gasket joints for cast-iron and ductile-iron pressure pipe and fittings	ANSI A21.11-1972
Two in. and 2¼ in. cast-iron pipe, centrifugally cast	ANSI A21.12-1971
Ductile-iron pipe thickness	ANSI A21.50-1971
Ductile-iron pipe, centrifugally cast in metal molds or sand-lined molds	ANSI A21.51-1971
Fabricated electrically welded steel water pipe	AWWA C201-66
Mill-type steel water pipe	AWWA C202-64
Coal-tar enamel protective coatings for steel water pipe	AWWA C203-66

Item	Standard No.
Cement-mortar protective lining and coating for steel water pipe, 4 in. and larger - shop applied	AWWA C205-71
Field welding of steel water pipe joints	AWWA C206-62
Steel pipe flanges	AWWA C207-55
Reinforced-concrete water pipe, steel cylinder type, not prestressed	AWWA C300-64
Prestressed concrete pressure pipe, steel cylinder type	AWWA C301-72
Reinforced-concrete water pipe - noncylinder type, not prestressed	AWWA C302-64
Reinforced-concrete water pipe, steel cylinder type, pretensioned	AWWA C303-70
Asbestos-cement pressure pipe	AWWA C400-72
Selection of asbestos-cement water pipe	AWWA C401-64
Gate valves - 3 in. through 48 in.	AWWA C500-71
Sluice gates	AWWA C501-67
Fire hydrants for ordinary water works service	AWWA C502-64
Wet-barrel fire hydrants for ordinary water works service	AWWA C503-70
Rubber-seated butterfly valves	AWWA C504-70
Backflow prevention devices - reduced pressure principle and double check valve types	AWWA C506-69
Ball valves, shaft-or trunion-mounted, 6 in. through 48 in., for water pressures up to 300 psi	AWWA C507-73
Installation of cast-iron water mains	AWWA C600-74
Disinfecting water mains	AWWA C601-68

Item	Standard No.
Cement mortar lining of water pipelines in place	AWWA C602-67
Installation of asbestos-cement water pipe	AWWA C603-65
Cold water meters, displacement type	AWWA C700-71
Cold water meters, turbine type for customer service	AWWA C701-70
Cold water meters, compound type	AWWA C702-70
Cold water meters, fire service type	AWWA C703-70
Cold water meters, propeller type, for main line applications	AWWA C704-70
Direct-reading remote registration systems for cold water meters	AWWA C706-72
Threads for underground service line fittings, with appendix on collected standards for service line materials	AWWA C800-66

7.3.1.1 Used Pipe

Used water mains that meet the above standards may be used again, after the pipe has been thoroughly cleaned and restored practically to its original condition.

7.3.1.2 Packing and Jointing Materials

Packing and jointing materials used in the joints of pipe should meet the standards of the American Water Works Association or the State.

Mechanical joints or slip-on joints with rubber gaskets are preferred.

7.3.1.3 Minimum Pipe Size

The minimum size of pipe shall be 15 cm (6 inch) diameter. See "Rating Schedule for Municipal Fire Protection" and "Guide for Determination of Required Fire Flow", Insurance Service Offices (formerly National

Board of Fire Underwriters), 160 Water Street, New York, New York, 10038.

Any departure in sizing should be justified by hydraulic analysis and future water use, and can be considered only in special circumstances.

Supply mains not intended to carry fire-flows should not be connected to fire hydrants. The flow in mains serving fire hydrants should be not less than 1890 Lpm (500 gpm) at 1.4 Kg/Sq. Cm (20 psi) residual pressure.

7.3.1.4 Valve, Air Relief, and Blow-off Chambers

Air and sediment accumulations may be removed through a standard fire hydrant, and compressed air and pumping may be used for dewatering mains through hydrants.

Chambers or pits containing valves, blow-offs, meters or other such appurtenances to a distribution system, should not be connected directly to any storm drain or sanitary sewer, nor should blow-offs or air-relief valves be connected directly to any sewer.

Such chambers or pits should be drained to the surface of the ground where they are not subject to flooding by surface water, or to adsorption pits underground.

The open end of an air-relief pipe should be extended from a manhole or enclosing chamber to a point at least 30 cm (one foot) above ground and provided with a 24-mesh screened, downward-facing elbow.

7.3.1.5 Fire Hydrants

Hydrant drains should be plugged and the barrels pumped dry during freezing weather; this plugging is recommended in all cases where ground water rises above the drain port.

Where hydrant drains are not plugged they should drain to the ground surface or to dry wells provided exclusively for that purpose.

Hydrant drains should not be connected to or located within 3 meters (10 feet) of sanitary sewers or storm drains.

Fire hydrants should be connected only to water mains adequately sized to carry fire flows. See Section 7.3.1.3 for flow considerations.

Hydrants should be located to permit flushing of all mains.

7.3.1.6 Installation of Mains

Adequate support should be provided for all pipes.

A continuous and uniform bedding should be provided in the trench for all buried pipe.

Stones found in the trench should be removed for a depth of at least 15 cm (6 inches) below the bottom of the pipe.

All distribution mains should be provided with sufficient earth or other suitable cover to prevent freezing.

The specifications should include:

a. pressure testing of the installed pipe at 50 per cent greater than working pressure in the line;

b. allowable leakage of the installed pipe as prescribed in AWWA C600, "Standard for Installation of Cast Iron Water Mains, 1964";

c. reference to applicable American Water Works Association standards and/or manufacturer's recommended installation procedures.

7.3.1.7 Water Pressure in System

The system should be designed to maintain a minimum pressure of 1.4 Kg/Sq. cm (20 pounds per square inch) at all points in the distribution system under all conditions of flow.

7.3.2 Water Services and Plumbing

Water services and plumbing should conform to relevant local and/or state plumbing codes, or to the National Plumbing Code, and to AWWA Standards, listed above in Section 7.3.1.

7.3.3 Cross-Connections

There should be no physical connection between the distribution system and any pipes, pumps, hydrants, or tanks whereby unsafe water or other contaminating materials may be discharged or drawn into the system.

The approval of the State should be obtained for interconnections between potable water supplies.

Neither steam condensate nor cooling water from engine jackets or other heat exchange devices should be returned to the potable water supply.

A 57-page booklet, "Cross-Connection Control Manual", has been prepared by the U.S. Environmental Protection Agency. It is available through the Supt. of Documents, U.S. Printing Office, Washington, D.C. 20402. This manual completely covers the subject of cross-connections including: purpose of control, public health significance of cross-connections, theory of backflow and backsiphonage, methods and devices for backflow prevention, testing procedures for backflow preventers, administration of a cross-connection control program, and provisions for a cross-connection control ordinance.

Another booklet (54 pages), "Cross-Connections and Backflow Prevention", is available from the American Water Works Association, 6666 W. Quincy Ave., Denver, Colorado 80235.

On January 26, 1970 the AWWA Board of Directors adopted a policy on cross-connections which reads as follows:

"The American Water Works Association recognizes that the water purveyor has a responsibility to provide its customers at the service connections with water that is safe under all forseeable circumstances. Thus, in the exercise of this responsibility the water purveyor must take reasonable precaution to protect the community distribution system from the hazards originating on the premises of its customers that may degrade the water in the community distribution system".

It is realized that the cross-connection control and plumbing inspections on premises of its customers are regulatory in nature and should be handled through the rules, regulations, and recommendations of the health authority or the plumbing-code enforcing agencies having jurisdiction. The water purveyor, however, should be aware of any situation requiring inspection and/or reinspections necessary to detect hazardous conditions resulting from cross-connections. If, in the opinion of the utility, effective measures consistent with the degree of hazard have not been taken by the regulatory agency, the water purveyor should take such measures as he may deem necessary to ensure that the community distribution system is protected from contamination. Such action would include the installation of a backflow protection device, consistent with the degree of hazard, at the service connection, or discontinuance of the service.

7.4.0 System Design (III-20)(VII-3)(VII-28)

7.4.1 Field Studies of Distribution Systems

The hydraulic performance of existing systems is determined most directly and expeditiously by pressure surveys and hydrant-flow tests. Such tests should cover all typical portions of the community, and, if need be, they can be extended into every block. The results obtained will establish available pressures and flows, and will reveal existing deficiencies. This information can then be made the basis of hydraulic calculation for extensions, reinforcements, and new gridiron layouts. Following completion of system improvements, additional tests can be conducted to determine how completely the desired changes have been accomplished.

7.4.2 Office Studies of Distribution Systems

No matter how well or completely the field study is done, hydraulic investigations of extensions, reinforcements, and new pipe networks can be brought to satisfactory conclusion only in the office. Hydraulic computations can be systematized so as to make their application a matter of simple calculation by slide rule, by use of pipe-flow tables, or by use of computer. Three methods of analysis will be found to be particularly useful: the method of sections, the Hardy-Cross method or one of its many modifications, and the method of equivalent pipes which may be applied alone or in conjunction with the Hardy - Cross method. The Hardy - Cross method and its offshoots employ calculation by successive approximation (or relaxation) by which systematic corrections are applied by trial and error to an initial set of assumed flows (or heads), until the network is balanced hydraulically. This kind of analysis is particularly adaptable to computer computation.

7.4.3 Main Size and Spacing

Minimum recommended sizes are 15 cm (6 inch) for residential developments supporting fire hydrants, and 25 cm (10 inch) for commercial developments. The particular main size for installation for a certain street should be selected in consideration of local load and conformity to the overall distribution grid plan.

7.4.4 Valve Spacing System

Valves should be placed in numbers and locations that give best possible control of the system consistent with cost limitations. Valves in smaller mains are more numerous than those in larger mains.

In transmission lines, valve spacing is determined by operating requirements, and thus are a matter of individual design.

In feeder mains, valves should be so spaced that each feeder loop can be effectively isolated. Usually this spacing should not exceed 910 meters (3,000 feet) in 40 cm (16 inch) feeders or 1,220 meters (4,000 feet) in 50 cm (20 inch) feeders.

Service main valves should be spaced so that adequate shutdown capability is provided without throwing large numbers of customers out of service.

In important districts, valves should be spaced to isolate sections of service main that are not longer than two sides of a block or a maximum of 180 meters (600 feet).

In residential areas or districts of lesser importance valves in 15 cm (6 inch) and 20 cm (8 inch) mains should be spaced no more than 305 meters (1,000 feet) apart, and in 25 cm (10 inch) and 30 cm (12 inch) mains no more than 610 meters (2,000 feet) apart.

Normally, at double intersections, three valves should be installed in 15 cm (6 inch) and 20 cm (8 inch) mains. At intersections involving 25 cm (10 inch) and 30 cm (12 inch) mains connecting to smaller mains, each smaller main should be valved. Single intersections involving 25 cm (10 inch) and 30 cm (12 inch) mains connecting to smaller mains, each smaller main should be valved. Single intersections normally should be fitted with at least two valves.

Service mains crossing creeks, railroads, and expressways should be valved on each side of the crossing. Each fire hydrant branch should be equipped with a control valve.

7.4.5 Valve Sizing

Valve sizes are normally the same as the water main in which they are installed, except that in mains 75 cm (30 inches) and larger, line valves are usually one size smaller than the main size.

Blow-off valves are usually sized 15 cm (6 inch) for mains 40 cm (16 inch) or smaller, and 20 cm (8 inch) for mains 50 cm (20 inches) and larger.

7.4.6 Valve Location

Valves are usually located on the extensions of the various street property lines involved. Where property lines are not involved, the valves should be placed so that they can be referenced with respect to certain obvious monuments. Valves should be readily accessible in the event of a main failure.

Branch mains, connecting to larger primary or secondary feeders which cross under arterial highways or streets should be valved close to the larger main before the crossing.

Blow-off valves and fire-hydrant valves should be located as close to the connected main as possible.

Buried valves normally are operated by conventional valve-box assembly and do not require vaults.

Air - or vacuum - release valves are normally located at hillcrests on the high part of the main involved.

7.4.7 Metering

Each service connection should be metered. There should be a routine testing program to check the accuracy of all meters in the system. Inoperable or malfunctioning meters should be repaired or replaced. Abnormal quantities of water use should be investigated to insure that service connections are not leaking or broken, especially where geologic conditions may prevent detection of leakage by observation.

Master meters which measure water supplied to the distribution system should be checked periodically for accuracy. They may either over-register or under-register, and the percent of error reflects directly on the percentage of distribution system losses. The proper selection and installation of the master is most important. When planning an installation, attention should be given to providing enough straight pipe ahead of the meter to ensure maximum uniformity of flow and, therefore, accurate registration. Provision should be made for testing the meter at least once each year. The meter can be tested in place without interruption of service by use of a test plug and a comparative test meter.

RATIONALE FOR DISTRIBUTION SYSTEM STANDARDS

7.1.0 General Protection Principles

The principles of protection cited in the Summary of Standards for this Section of the Manual are well founded in good sanitary engineering practice. For the most part, these principles have been taken from the EPA "Manual for Evaluating Public Water Supplies", the EPA "Cross-Connection Control Manual", the AWWA Manual "Water Distribution Training Course", the AWWA Standards, and the "Recommended Standards for Water Works" of the Great Lakes - Upper Mississippi River Board of State Sanitary Engineers.

Many failures to meet the bacteriological requirements of the Federal Drinking Water Standards are directly related to the use of poor operating and maintenance procedures for distribution systems or to the presence of sanitary defects in the system. Some causes that contribute to poor bacteriological quality are: insufficient treatment at the point of production; cross-connections; improperly protected distribution system storage; inadequate main disinfection; close proximity of sewer and water mains; improperly constructed, maintained, or located blow-off, vacuum, and air relief valves; and negative pressures in the distribution system.

The distribution system of a water supply presents many opportunities to impair water quality. The time of detention within the system's mains may be quite long, and many potential inlets usually exist for polluting materials, such as services, blow-off and relief valves, and cross-connections. Any list of protective measures should include proper procedures for the laying, flushing, and disinfecting of new or repaired mains; maintenance of chlorine residuals when a main is returned to service; and adequate separation of water and sewer lines. Blow-off and relief valves can adversely affect water quality if improperly constructed or installed, or if located in sumps subject to flooding or in other places subject to inundation by wastes or poor quality water.

The system should be designed to supply adequate quantities of water under ample pressure and should be operated to prevent, as far as possible, conditions leading to the occurence of negative pressure. Steps to prevent negative pressure should include minimizing planned shutdowns, providing adequate supply capacity, correcting under-sized conditions, and properly selecting and locating booster pumps to prevent the occurence of a negative head in piping subject to suction. Continuity of service and maintenance are essential to prevent back-siphonage.

Contaminated secondary water sources, where cross-connected to a community system, can seriously degrade the water in the system. Many water-borne disease outbreaks have resulted from such connections; (VII-145)(VII-161). Cross-connection hazards may be divided into those resulting from the interconnection of a non-potable water supply with a potable supply, and those resulting from backflow caused by the development of negative pressure in the water distribution systems of premises having internal piping defects. Negative pressure can develop from such causes as main breaks, inadequate supply pressure, undersized mains, unusual water demands, and shutdowns for maintenance or repair. On the consumer's premises, backflow can also be caused by back pressure from cross-connections to boilers, elevated storage tanks, hydro-pneumatic systems, pumps, circulating systems, and auxiliary water supply systems. To deal with these problems, an active cross-connection control and elimination program and an aggressive program of reducing, to a minimum, the frequency of occurrence of negative pressure in the system should be established.

7.1.1 Quantity and Pressure

The minimum pressure requirement is intended to reduce hazards of contamination through cross-connections and back-siphonage.

7.1.2 Quality

The needs for protecting the quality of water during its residence in the distribution system as recited in Section 7.1 above, also apply to the palatability of the water. If poor-tasting water is delivered for any length of time to consumers, many will seek drinking water from other sources which may taste better but be of inferior sanitary quality.

7.1.3 Quality Sampling

The occurence of quality deterioration in the distribution system is often localized and intermittent, so that the requirements for sampling location and frequency must take these facts into account.

7.1.4 Valves

Valving requirements are intended to reduce the import, frequency, and extent of shutdowns of portions of distribution systems.

7.1.5 Disinfection

The requirement for the presence of adequate residual disinfectant in the water being distributed to consumers is primarily to provide some protection against quality deterioration, but it also provides a means for detecting localized sources of contamination and spots of poor water circulation through the disappearance of residuals.

7.1.6 Cross-Connections

The need for elimination of these system defects is presented in Section 7.1 above.

7.1.7 Leakage

Excess leakage is an economic waste. Further, points of leakage when the system is under pressure are also potential points of infiltration when pressures are low or negative.

7.1.8 Submarine Lines

Lines submerged in non-potable water are a special cross-connection case, and special construction precautions are necessary.

7.1.9 Repairs, Replacements, and Extension of Mains

These conditions involve the introduction of new materials and loss of pressure into parts of the distribution system, both of which present hazards of contamination and suitable precautions must be taken.

7.2.0 Pipeline Location and Protection

7.2.1 Location

7.2.1.1 Separation of Water Mains and Sewers

The hazards associated with the close proximity of sewage and potable water and inadequate protection of the drinking water supply are obvious. The Standards prescribed are based on experience with defects and incidents observed over many years of operation of public water supplies and water-carried waste systems.

7.2.1.2 Drains

The possibility of water system drain lines becoming inlets for contaminated waters under low water system pressure conditions is, again, rather obvious, particularly when the drain is directly connected to a drainage or sewerage structure.

7.2.1.3 Trench Flooding

The elimination of installing water lines in flooded trenches is essential if the completed lines are to be adequately disinfected by normal procedures.

7.2.1.4 Frost

Physical damage (cracking or breaking) to water lines can create sanitary hazards to water quality in addition to interruption in service.

7.2.1.5 Dead-Ends

Stagnant water in dead-end lines is subject to deterioration in quality by: loss of residual disinfectant; growth of iron bacteria and sulfate - reducing bacteria; production of hydrogen sulfide; corrosion; deposition; and in other ways.

7.2.2 Protection

7.2.2.1 Pressure

The need for a minimum pressure requirement is covered under Sections 7.1 and 7.1.1.

7.2.2.2 Caulking Materials

Experience has shown that certain joint caulking materials can harbor and support bacterial growth in pipelines.

7.2.2.3 Lime Deposits

Lines having their effective diameter decreased by deposits of lime or bacterial slimes can produce low system pressures and the sanitary hazards associated therewith.

7.2.2.4 Corrosion of Service Lines

Corrosion of lead, copper, and other non-ferrous metal pipe can result in the solution of toxic metals in water delivered to consumer taps. (VII-22)

7.2.2.5 Corrosion Control

Specifications for chemicals used in treatment for corrosion control are necessary to assure that trace amounts of harmful impurities are not introduced to the water along with the chemical being used.

7.2.2.6 Surface Water Crossings

The need for the special precautions prescribed here are given under Sections 7.1 and 7.1.8 above.

7.2.2.7 Plastic Pipe

Some toxic materials used in the manufacture of plastic pipe are subject to leaching and pipe containing such toxic materials should not be used for drinking water service.

7.2.2.8 Sanitary Precautions

The needs for these Standards are given under Section 7.1 and 7.1.5 above.

7.2.2.9 Leakage

The necessity of limiting system leakage is given in Sections 7.1 and 7.1.7 above. Ten per cent is a value which can be readily attained with proper attention to this problem.

7.2.2.10 Disinfection

The AWWA Standard in this regard is one which is widely used and proven in field practice.

7.2.2.11 Bacteriological Examination

The prescribed testing is a necessary check on the adequacy of system disinfection procedures.

7.3.0 Materials and Installation

7.3.1 Distribution Standards

The AWWA Standards incorporated herein by reference are widely used and accepted standards of the water works industry. A number of factors must be weighed in selecting the best type of pipe for installation in different parts of a water system including: costs, availability, durability, corrosion resistance, initial and sustained carrying capacity, and ease of installation and maintenance. In pipeline design maximum internal pressures and external trench loadings must be considered.

Special installations, such as those under streams, bridges, railroads, or highways may require special materials and treatment.

A certain amount of repair work is unavoidable, and a stock of repair items should be maintained. Experienced on-the-job supervision can contribute greatly to efficiency of repairs and reduce the length of service interruptions.

7.3.1.1 Used Pipe

The use of used pipe, restored to new condition, is subject to approval of the State.

7.3.1.2 Packing and Jointing Materials and Methods

The AWWA Standards and those of most States exclude the use of packing and jointing materials which harbor or support bacterial growth or which may be subject to leaching of toxic materials.

Methods for jointing various types of water pipe have been improved greatly in recent years. Today joints can combine watertightness, flexibility, and ease of economy and installation.

Rubber-gasketed bell-and-spigot slip joints have largely superseded all other types of joints for use with cast-iron pipe. A slip-on rubber-gasketed joint has been developed for asbestos-cement and for concrete pipe. Steel pipe may be welded or have plain ends jointed with mechanical rubber-gasketed couplings, or steel pipe may also have bell-and-spigot rubber gasket joints.

7.3.1.3 Minimum Pipe Size

This Standard is intended to assure minimum system pressures required for sanitary protection and to provide fire flows.

Design work involving major hydraulic analyses and pipe sizing should be done by competent hydraulic engineers who are thoroughly familiar with both the theoretical and practical aspects of hydraulics. Such men may be available within the utility, or it may be advisable to hire outside engineering consultants. Some of the fundamental principles of hydraulics should be understood by all who are engaged in the planning, design, or operation of distribution systems.

7.3.1.4 Valve, Air Relief, and Blow-off Chambers

These specific requirements are intended to meet the needs quoted under Sections 7.1 and 7.1.4 above.

Valves should be placed in some standard area, such as street or curb lines, to facilitate their location. A valve box should always be placed over a buried valve with its cover at the street grade. Geared valves sometimes have enclosed gear and grease cases and are placed directly in the ground. Large valves are often placed in brick or concrete vaults.

7.3.1.5 Fire Hydrants

Again, these Standards are to implement the needs quoted in Section 7.1 and 7.1.4 above.

Fire hydrants should be so located as to be completely accessible to the fire department and yet, as far as possible, be protected from damage from vehicles and out of the path of pedestrians. Hydrant nozzles should be set to grade and not less than 30 cm (12 inches) above grade. They should be so pointed as to be accessible, but should be a sufficient distance back from curb lines to escape vehicle damage. Fire hydrants are now rarely connected to distribution mains except through properly gated 15 cm (6 inch) or larger hydrant laterals. Hydrants are made to be self-draining through drain ports when shut off. To accomplish this drainage, a pocket filled with gravel or crushed stone at least 60 cm (2 feet) in diameter should be provided under and around the hydrant base. In clay ground this pocket may need to be larger. The hydrant and lateral both should be braced or tied with rods to protect against shifting due to unbalanced water pressure.

7.3.1.6 Installation of Mains

These Standards are for the purpose of preventing physical damage to pipelines which can produce sanitary hazards to water quality.

The installation of water mains involves transporting and handling the pipe and appurtenances; ditching and excavation; laying, joining, testing, and disinfecting the pipe; backfilling the trench; and replacement of road, paving, and sidewalk surfaces. Complete specifications for the installation of pipe and fittings are given in an AWWA standard, C600.

Excavation can be carried out in several approved ways - by hand labor, power shovel, back hoe, or trenching machine. In many respects the back hoe has proved to be a good piece of equipment for installing pipe, particularly in the larger sizes. It is effective in doing the excavation, and can handle the pipe from the trench side to its completed installation.

The trench should be opened only so far in advance of pipe installation as is necessary. It is best to keep the trench as narrow as possible and to shape the bottom of the trench to form a complete bed. Blocking should preferably not be used under pipe, but if it is used it should be removed as soon as preliminary tamping of fill around the pipe provides full bearing. If rock is encountered, or if the bottom material is undesirable for bedding, it should be excavated 15 cm (6 inches) below the grade and refilled with sand or fine gravel tamped in place.

When the trench is suitably prepared, the pipe should be lowered and joined. Care should be exercised in handling so that it is not damaged. Various pipe manufacturers give special instructions for the handling and jointing of their pipe.

Because the "shove in" or "roll on" pipe joints have largely replaced joints poured with lead, sulfur compounds, and cement, details of these older joints are not set forth here. Reference should be made to AWWA C600 for the details of making such joints.

Sulfur compound joints were commonly used for cast-iron pipe during the period 1920-50. Much trouble has been, and is being, experienced with joint failures and breakage of the bells of such joints under certain soil conditions. This is generally attributed to the expansion of the joint material, and much controversy has arisen concerning it. Not much can be done to correct such installations except at considerable expense. Bell clamps may be successful in stopping breakage or the joint can be cut out and refilled with some other joint material.

The joining of the pipe should be done carefully. Each type of pipe requires special joining procedures. The distinctive sound of a joint being "home" should be heard on pushing the pipe together. If rubber gaskets are used, an inspection of completed joints should be made with "feelers" or by some other method to insure that the gaskets are properly seated. The newer types of joints are usually pulled together with "come-alongs," bars, a back hoe, or a bucket and sling. The same methods are used in installing valves, fittings, and fire hydrants as with straight pipe.

Blocking or firmly positioning tees, bends, caps, plugs, hydrants, and other fittings is an important part of pipeline installation. Any unbalanced pressure in a pipeline must be counterbalanced with blocking or positive ties, inasmuch as many modern joints can easily be pulled apart.

Sleeves are often used in the assembly of valves in pipelines. Care should be taken that pipe is solidly together, or "spacers" should be provided to prevent lengthwise movement of the pipe resulting from the unbalanced pressure exerted by valve closure.

After pipe, fittings, valves and other appurtenances are installed and inspected, a selected backfill is placed in the trench - that is, the backfill should be free from rock, large stones, cinders, or other unsuitable substances to avoid damage and to produce a dense, compact backfill. Backfill material should be tamped in layers around the pipe and for a height of at least 30 cm (12 inches) over the pipe barrel. If possible, joints should be left exposed until pressure and leakage tests are concluded. Where trench settlement is unimportant the remainder of the trench can be filled with excavated material pushed in by bulldozers and mounded over the pipe trench. In streets or other locations where settlement is undesirable, the backfill should be consolidated by tamping or by flooding with water to the top of the trench. Local highway regulations often dictate what the backfill shall consist of and what the methods used to place it should be.

Proper restoration of paving, sidewalks, lawns, or shrubbery is important, for the general public will remember the restoration and cleanup much longer than the reason for installing the invisible main.

7.3.1.7 Water Pressure in System

Reduction of system pressures below 1.4 Kg/Sq. cm (20 psi) exposes the water to unnecessary and avoidable risks of contamination.

In laying new mains, hydrostatic-pressure tests and tests for leakage should be made whenever possible, particularly on major installations. To make such tests each valved section of the main should be slowly filled with water and air should be expelled from the line through hydrants or taps made at the high points.

The pressure test is usually made by means of pump and test gage and at a test pressure at least 50 per cent greater than the working pressure in the line. The test pressure should be maintained for at least 1 hour and an examination should be made of the line for visible leaks or pipe movement. Any obvious defects should be fixed before the leakage test is made.

The leakage test should be conducted after the pressure test is completed. Leakage tests are conducted by measuring, through a calibrated meter, the amount of water which enters the test section under normal working pressures for a period of at least 2 hours.

7.3.2 Water Services and Plumbing

The provisions of the National Plumbing Code, state and local plumbing codes, and AWWA Standards which are incorporated under Section 7.3.2 are necessary to protect water users against recognized hazards in building plumbing.

Each service connection consists essentially of a connection to the distribution main, a length of service pipe leading to a curb cock or turnoff valve located outside the curb line or near the property line, and another length of service pipe to the plumbing system of the premises. The service pipe is generally connected to the distribution main by means of a corporation stop inserted in the main. The insertion is normally accomplished while the main is in service and under pressure, and is thus known as a "wet" connection. Occasionally outlets are provided in the main when it is originally installed, particularly if the service connections are large. The corporation stop can be turned to shut off the flow in the service line, as is often done to reduce the possibility of leakage when the service connection is discontinued. Ordinarily, water service to the premises is turned on or off at the curb stop located near the curb and accessible through a curb box placed over it.

A meter may be inserted in the service line either at or near the curb stop or inside the premises served. If an outside meter setting is used, the curb stop may be incorporated in it.

Every water utility should have definite regulations and specifications for service and meter installations and should set forth responsibility for payment of costs. The specifications may be in the form of sketches which detail how the service line is to be installed, sizes and kinds of approved service line materials, and any other information necessary to provide a complete understanding of installation requirements. Lack of such knowledge on the part of the customer often can result in misunderstandings and strained relations.

7.3.3 Cross-Connections

Supporting data for the prohibition of cross-connections by the Standards of this Section 7.3.3 are given in the Standard 7.3.3 and the publications referred to therein.

7.4.0 System Design

7.4.1 Field Studies of Distribution Systems

This Standard merely points to the value and need for such studies. Detailed descriptions of equipment, methods, and procedure are to be found in references listed in the Bibliography of this Manual.

7.4.2 Office Studies of Distribution Systems

Again, this Manual only points to the benefits and needs of such studies, and further information is available in materials referenced in the Bibliography which follows.

7.4.3 Main Size and Spacing

This Section recites general current practice in this regard.

7.4.4 Valve Spacing

This Section points out considerations involved in arriving at the number of valves required.

7.4.5 Valve Sizing

This Section recites general current practice in this regard.

7.4.6 Valve Locations

This Section relates factors involved in choosing valve location.

7.4.7 Metering

This Section describes the value and need for metering. Metering can save water and energy and provide valuable information about system operation.

SECTION VIII   OPERATION AND MAINTENANCE

SUMMARY OF STANDARDS FOR OPERATION & MAINTENANCE

8.1.0 Operation and Maintenance Program (VIII-5)(VIII-8)(VIII-66)(VIII-78)(VIII-85)(II-72)

All units of a public water supply system should be operated and maintained in an effective and efficient manner in accordance with all requirements of the State and these Standards. In case of conflict, the more stringent requirement apply.

8.1.1 Supervision

A competent person, qualified by experience and education should be in charge of the operation and maintenance of each public water supply. Certification through the appropriate state certification program (whether voluntary or mandatory) will be considered satisfactory evidence of competency.

8.1.1.1 Number and Types of Staff

The size and qualifications of the staff which operates and maintains a public water system should be subject to review of the EPA and to recommendation through the State to the purveyor (see Sections 10.1 and 10.3).

The chief operator should be retained by the water utility by the time construction of the water treatment plant is 50% complete so that he can become familiar with the plant layout, piping, underground utilities, checkout of all equipment, and to oversee staff development and training.

Treatment processes should be maintained by competent personnel continuously. The State may waive this recommendation for well water systems serving small populations when adequate surveillance is provided.

8.1.1.2 Delegation of Responsibility

The utility should have a well-defined policy for delegation of responsibility among its personnel for all phases of operation and maintenance.

8.1.1.3 Federal and State Inspections

To provide assurance of effective, efficient, continuous operation of water system facilities, State agencies should establish and maintain appropriate facility

Preceding page blank

inspection and technical assistance programs to identify operational deficiencies and to insure that appropriate remedial action is taken to correct deficiencies.

State agencies should conduct or provide for, an annual inspection, facilities to determine whether these facilities are operated efficiently and effectively in accordance with plant design.

The inspector should record the following information:

a. General information, including: date of inspection; plant identification and locations; name of inspector and title; type of plant and distribution system; estimated total population served as well as industries served.

b. Plant loading performance data, including: average daily flow (MGD); peak flow rate (MGD); percent daily industrial water use; and summary of laboratory analyses data on raw and tap water.

c. Information on operating personnel, including: staff complement and qualifications of personnel in each job category; total manhours per week; number of State certified or licensed personnel; staffing deficiencies; staff vacancies; staffing needs not budgeted; training needs and annual O & M Budgets. Also included should be an identification and narrative of any facility problem traceable to personnel or training deficiencies.

d. An identification and brief discussion of significant operational problems or difficulties.

e. An evaluation and report on the facility, including: adequacy of operation and plant performance with regard to State, Federal, or other requirements; general housekeeping and maintenance adequacy; testing and reporting adequacy; and recommendations for corrective actions.

f. Appropriate additional operation and maintenance data and information pertinent to the conditions found at the plant or elsewhere in the water system at the time of inspection.

Copies of the inspection results should be distributed by the State to the subject water system; two copies to the EPA Regional Office, including a copy of the report transmittal letter to the inspected facility and/or the authority responsible for management.

In addition to thorough annual inspections as described above, routine interim inspections should be conducted by the State. The EPA Regional Office should receive a copy of the reports on interim inspections.

Prompt and meaningful follow-up action should be taken by the State to assure correction of inadequacies and deficiencies noted at inspections.

Where major deficiencies are involved, a copy of official State correspondence, notices or orders to a municipality and follow-up inspection reports shall be sent to the EPA Regional Office.

Wherever possible, in correcting deficiencies in operation, the State should coordinate with the design engineer responsible for the subject facility.

The consulting (design) engineer and the State should be involved in the start-up of new facilities.

8.1.2 Analyses and Records

The water purveyor should keep such records of water system operation and water analyses as necessary to demonstrate compliance with the Federal Drinking Water Standards and local Standards. The purveyor should keep these records available for inspection by the State and representatives of the EPA; should send copies to the State or the EPA upon request; and should submit copies to the State where required by Federal Drinking Water Standards, State law, or regulation.

8.1.2.1 Annual Summary

At the end of each calender year the water purveyor should prepare a summary of the utility's operation for the preceeding twelve months. This summary should be available for inspection and review of the State and representatives of EPA. The annual summary should contain, as a minimum, the following information: number of services and meters; average annual daily demand, maximum daily demand, and peak hourly demand; the normal and extreme ranges of distribution system pressures; a tabulation of the major components of the system and additions or changes made during the year; and a summary of the physical bacteriological, and chemical quality of water maintained in the system and delivered to consumers as compared to the Federal Drinking Water Standards.

8.1.3 Public Notification of Variances, Exemptions, and Noncompliance with EPA "Interim Primary Drinking Water Standards, March 14, 1975".

a. The supplier of water shall give notice to the persons served by the public water system of any failure on the part of the system to comply with the requirements (including monitoring requirements) of this subpart. The supplier of water shall give the notice required by this paragraph not less than once every three months during the life of the noncompliance:

   1. by publication on not less than three consecutive days in a newspaper or newspapers of general circulation serving the area served by such public water system, which newspaper or newspapers shall be approved by the State. With respect to the public water systems operated by Federal Agencies, the newspapers cited in this paragraph shall be approved by the Regional Administrator.

   2. by furnishing a copy thereof to the radio and television stations serving such areas as soon as practicable but now later than 36 hours after confirmation of the noncompliance with respect to which the notice is required; and

   3. by inclusion with the water bills of the public water system at least once every three months if the water bills are issued at least once every three months, and with every water bill if they are issued less often. If water bills are not issued, other means of notification acceptable to the State may be used. The notice required by this paragraph shall state at least that the public water system fails to monitor, operate the system or provide water which meets all the requirements of this subpart and shall state with particularity those requirements for which there is noncompliance. If a quantitative limitation has been exceeded, the notice shall state what the Federal or State limitation is, and at what level of performance the water supply system has been operating.

b. The supplier of water shall give notice pursuant to the procedures set forth in paragraph a. of this section - -

   1. when his system has received a variance under the 1974 Safe Drinking Water Act, and shall continue the notification process at no less than three month intervals during the life of the variance;

2. when his system has received an exemption under the 1974 Safe Drinking Water Act, and shall continue the notification process at no less than three month intervals during the life of the exemption; or

3. when his system has failed to comply with any schedule or control measure prescribed pursuant to a variance or exemption and shall continue the notification process at no less than the three month intervals during the life of the variance and exemption.

8.1.4 Water Utility Action Required for Noncompliance with EPA "Interim Primary Drinking Water Standards, March 14, 1975". (IPS).

The IPS set maximum contaminant levels for: inorganic chemicals, organic chemicals, pesticides, turbidity, and microbiological contaminants. If the water furnished by a public water system contains a level of any contaminant which is 75 per cent or more of the maximum contaminant level, the supplier must meet certain specified sampling and analytical requirements as set forth in the IPS. If the supplier of water determines or has been informed by the State that the maximum contamination level for a contaminant has been exceeded, then certain specified reporting and public notification requirements must be met as set forth in the IPS.

8.1.5 Operation and Maintenance Manual

For each water treatment plant, the utility should assemble a loose-leaf compilation of operating and maintenance instructions for all equipment and appurtenances including recommendations and explanations by the consulting engineer of the design and functions of various parts of the plant. The manual should be indexed by the processes, facilities, and equipment for which it was prepared.

The operation and maintenance manual should contain a simplified schematic diagram of major pipelines, valves, and controls. Additional diagrams should contain enlarged detail of complicated piping areas. The pipelines, valves, and controls should be clearly marked as referenced in the detailed operation procedures.

The various manufacturers' maintenance schedules (daily, weekly, monthly, etc.) should be summarized with reference to the page in the manufacturer's operation and maintenance manual. Also, a cross-reference lubricant chart indicating equal lubricants produced by various major manufacturers should be furnished.

In regard to types of treatment the manual should contain technical detail in simplified language, describing precisely how each process should be operated and controlled for maximum effectiveness. Manufacturer's manuals should be referenced when useful to this explanation.

The operation and maintenance manual should contain emergency procedures and provide appropriate instructions to treatment facility personnel to insure that they know their assigned responsibilities for properly responding to various types of emergency situations and thus eliminate or minimize resulting adverse effects from such incidents.

For further detail on preparation of O & M Manuals see EPA publication EPA-430/9-74-001, "Consideration for Preparation of Operation and Maintenance Manuals".

8.1.5.1 Operator Training

Water treatment plant personnel should be trained continuously. In large plants, a class or conference room properly equipped with visual aides is of great assistance for in-plant training courses. In smaller plants greater reliance for operator training may be placed on state, federal, university, organizational, and private short schools and other training courses.

8.1.6 Operating Well Pumps

Continuous pumping is preferable to stopping and starting. The pumping rate should be such as to minimize the number of cycles of starting and stopping. No period of operation should be less than 15 minutes.

8.1.7 Pump Operation Checks

In starting an electric-motor-driven centrifugal pump the following procedure is recommended: (1) check the lubrication; (2) prime the pump and make sure that the pump and suction piping are free of air; (3) if power is limited, reduce current surge on startups by starting the pump with the discharge valve closed or throttled; (4) open the discharge gate slowly as soon as pump is running; (5) check the packing glands and see that the water seals are properly functioning; and (6) check the running current and investigate any abnormal current demands (see Section V).

There are a number of causes of centrifugal pump trouble which are good to know about. Forty-seven possible causes of operating trouble with centrifugal pumps are listed in Table 3.5, page 40, "AWWA Manual M8, Water Distribution Training Course".

8.1.8 Basin Operations

To prevent impairment of water quality, organic matter, animal life, and debris should either be kept out of basins used in treatment or quickly removed from them. Sedimentation basins should be periodically gaged for sludge accumulation and any sludge should be removed from them before the operating efficiency is degraded or before tastes or odors are imparted to the water. In basins equipped for mechanical sludge removal, the operation of these devices should be checked from time to time to ensure proper functioning. In winter, it is important to prevent short circuiting of basin flow due to ice formation. Algal growths in basins should be controlled by regular inspections and treatment. Drainage of surface water into basins should be avoided.

8.1.9 Operation of Chemical Feeders

Accurate proportioning of treatment chemicals to the flow of water being processed requires accurate measurement of both the water flow and the amount of chemicals being fed, usually within plus or minus 3 per cent.

All rate-of-flow measuring devices should be checked regularly. Similarly, chemical feeders should be routinely checked. Catch the feed for a period of time and weigh the catch on scales. Compare this with storage records. In some cases, the accuracy of chemical feed can be established from chemical analysis of the water being treated. Every plant should develop a testing routine for its chemical feed and flow-recording equipment.

Plant operating personnel should be alert to any trends or changes in the characteristics of the raw water, both on a long-range basis and on the short-term basis needed for day-to-day operations.

Operators should maintain continuous communication with plant management and appropriate regulatory agencies so that plant inadequacies are detected early, thus affording lead-time to diagnose and resolve problems before they impair quality control in the plant.

8.1.10 Filter Operation

Ineffective filtration can result from dislocations in the gravel bed, dirty filter media, and malfunctioning of filter-rate controllers or backwash pumps. Probing of the entire filter area to establish the upper surface of the gravel bed will reveal if gravel mounds exist through which water can pass at higher-than-desirable rates. Inspection for mud balls and shrinkage away from the filter wall will give an indication as to whether or not filters are being properly backwashed. Trends in the initial loss-of-head readings (immediately after filter backwash) may also indicate adequacy of filter cleaning. Loss-of-head gauges and filter rate-of-flow controllers should be checked periodically. As water temperature and other conditions dictate changes in filter operating instructions should be made.

Plant flexibility should be used to get the maximum treatment out of the facility on a day-to-day basis. This includes making such process adjustments as may be indicated by the monitoring system.

The flexibility in routing flows that is provided in the design shall be used to allow preventive maintenance and repairs to be carried out without discharging inadequately treated water.

8.1.11 Operation of Finished Water Tanks and Reservoirs

Routinely check covers, vents, and screens for defects. Avoid allowing reservoirs to get so low at times of heavy draft that vortexing and entrainment of air can result. Determine whether deposits are forming in tanks and reservoirs, and set up a cleaning program in accordance with the needs. Avoid the use of protective coatings, preservatives, or joint sealers that can impart taste, odor, or toxic chemicals to the water.

8.1.12 Operation of Distribution Systems

Maintain a free chlorine residual of not less than 0.2 mg/l in all parts of the system. See EPA, IPS, paragraph 14.16. If necessary at storage reservoirs with long detention periods, provide for redisinfection of water leaving the reservoir in order to maintain the required chlorine residual.

Set up a main-flushing program commensurate with the needs of the system.

Set up a routine program for flushing dead end lines.

Set up a routine program for inspection of pumping facilities including wet and dry wells.

Maintain adequate records of complaints about poor water quality. Inspect pipelines at every opportunity for corrosion, deposition, and sediment accumulation. Control of corrosion through proper in-plant treatment is essential. Well kept records and maps of pipelines and appurtenances are essential to the efficient operation of distribution systems.

8.1.12.1 Main Disinfection

Newly laid or repaired mains should be disinfected before use in accordance with AWWA Standard C601-68.

8.1.12.2 Pipe Joints

In laying main extensions or in repairing mains use only rubber rings, asbestos rope, or treated paper rope as yarning or packing material. Jute, hemp, or similar organic packing materials are not recommended.

8.1.12.3 Negative Pressure

The distribution system shall be operated so as to avoid development of pressures less than 1.4 Kg/Sq. Cm. (20 psi).

8.1.12.4 Cross-Connection Control

Each water utility should have a regular program for the detection and elimination of cross-connections and the prevention of back-siphonage (see EPA, "Cross Connection Control Manual", 1973).

8.1.13 Treatment Chemicals and Other Supplies

Each water utility should have a regular system for anticipating needs for chemicals and other operating supplies, and for ordering and securing delivery of such essential supplies so as to meet all operational requirements without interruption of water service. Provisions should be made to take care of supply needs during week-ends, holidays, and delays in delivery.

8.1.14 Maintenance Program

An effective equipment maintenance program is necessary to insure that all equipment is kept in a highly reliable operating condition. It is the responsibility of the plant management to provide sufficient funds for maintenance, repairs, spare parts, and standby equipment to keep the plant, pumping stations and related appurtenances operating satisfactorily.

Each water utility should have adequate staff, tools, equipment, work area, stock of spare parts, and other essentials for maintaining all parts of the system without undue or unnecessary interruption of service.

Each public water system should also have a planned program of preventative maintenance which includes regular inspection, lubrication, prompt restoration of worn parts, servicing, and other maintenance in order to minimize breakdowns and to thus permit continuous functioning of the system.

To prevent breakdowns, all mechanical equipment should be systematically inspected, lubricated, and overhauled. To do this requires the keeping of a system of permanent records on every operating piece of equipment. It is unwise to depend upon memory or the personal notes of supervisors for the scheduling of preventative maintenance. A planned maintenance program should be designed to accomplish the following objectives: (1) schedule inspections, lubrication, and necessary repairs of regular and standby equipment on a definite periodic basis; (2) time preventive maintenance work so that it is evenly distributed throughout the year; (3) systemize scheduled maintenance work so that it is referred properly and without fail to the maintenance department or crew; (4) provide a simple procedure for changing the frequency of inspections of any or all items required; (5) create a dated record, easily and quickly accessible, of the maintenance work required and performed upon each item of equipment; (6) standardize each inspection procedure, itemizing and illustrating all items to be covered; (7) schedule maintenance work so that similar or related work is done consecutively; (8) provide a readily accessible record of the maintenance work to be performed upon each piece of equipment at given times during the year; (9) create a means for determining the cost per year for maintaining any item of equipment.

Essential maintenance information should be displayed at or near equipment.

The layout and design of manual controls should be such as to facilitate maintenance.

Preventative maintenance shall commence immediately upon installation of the equipment and not be delayed until the facility is placed in operation.

8.1.14.1 Plant Grounds

Cut weeds and grass, pickup litter, exclude animals by fencing, store materials in neat, orderly stacks.

8.1.14.2 Raw Water Reservoirs

Keep free of debris and cut grass and weeds on banks. There should be no evidence of wastewater or sewage entering the reservoir. Algal growth shall be kept to a minimum. Intake screens should be kept free of leaves and other trash.

8.1.14.3 Buildings

Yard, maintenance tools, and equipment should be neatly stored in a place provided therefor. Adequate cleaning equipment should be kept on hand and stored in a suitable location. Trash cans and waste baskets should be provided and emptied daily. There should be no excessive leaking of water at pumps, in pipe galleries, or at other locations. Chemical and chlorine storage rooms should be kept in an orderly manner. Empty bags should be disposed of promptly. Floors should be kept clean.

8.1.14.4 Basins and Clearwells

Drain, hose, scrub, and scrape as necessary to keep algal growths and chemical deposits off walls. Inspect clearwells periodically to insure cleanliness and freedom from sediment. Drain and clean as necessary, followed by disinfection.

8.1.14.5 Chlorinator Room

Keep door closed except for entry and exit. Check to be sure lights and exhaust fan are operating from switches outside the chlorinator room. There should be no equipment in room except for chlorinators and evaporators. An approved gas mask shall be mounted outside the chlorinator room with filter within proper dates. See Section 10.7.0 for additional safety considerations.

8.1.14.6 Pump and Well Houses

Floors should be clean and free of litter. There should be no cracks in the floor, particularly near well casing. There should be no storage of equipment or supplies other than those needed in the pump house.

8.1.14.7 Pumps and Equipment

All pumps and equipment should be kept clean. Packing should be maintained in pumps and pipe joints to prevent leaking. Seals between pumps and well casing should be in good working order. All valves and gauges should be in good working order. Pressure tanks should be in good repair with no leaks, and pressure gauges shall be in good order. Pumping equipment should be well lubricated, and have a minimum of vibrations.

An equipment numbering system should be developed in some logical order for plant equipment so that both equipment function and location are evident in the identification number.

8.1.14.8 Pipelines

The water utility should have a regular program for locating and repairing leaks. In filling pipelines care should be taken to avoid entraining or entrapping air. Mains, and in particular deadends, should be flushed periodically and thoroughly. Hydrants, valves, meters, and other appurtenances should be inspected periodically and kept in good order.

8.1.14.9 Storage Tanks

Metal tank interiors should be kept clean, free of rust, and painted with an approved paint. Exteriors should be free of rust and kept painted. Trap doors, manholes, and other entrances should have tight-fitting covers and be kept closed when not in use. Any such doors which are exposed to vandalism should be kept locked. There should be no leaks. There should be no unnecessary openings. Vents shall be screened and in good condition. Ladders, balconies, and handrails on elevated tanks should be safe and in good condition. Water level indicators on elevated tanks should be maintained in operating condition and good repair.

8.2.0 Budgeting and Financial Planning(VIII-5)(VIII-85)

8.2.1 Long Range Financial Planning

The one factor which determines more than any other the degree of success which a water utility attains in fulfilling the needs of the public it serves is the factor of long-range financial planning. At the outset, this Manual points out the desirability for each utility to develop a comprehensive plan for development of the ultimate water system for the area to be served. A good plan for the physical facilities required is a sound basis for financial planning of system improvements, but many excellent long-range engineering plans have never been implemented due to the lack of proper long-range financial planning. The importance of such financial planning cannot be overemphasized, it is basic to everything the utility does.

8.2.2 Sources of Income

Available to the publicly owned water utility are three sources of revenue; taxes, revenues from sales (service charges), and contributions in aid of construction. By existence of these sources, credit is established and used to borrow money through the issuance of bonds or notes. Then over a period of time money borrowed will be repaid out of one or more of these sources of revenue. Ordinarily either general obligation or revenue bonds may be issued.

Privately owned water companies are usually financed entirely by bonds or other forms of debt securities, with a substantial equity contributed by the owner.

8.2.3 Expenses

The major categories of water department expenses are operation and maintenance, capital improvements, and debt service.

8.2.4 Accounting and Budgeting

For detailed information on these matters reference is made to "AWWA Manual M10, Simplified Accounts Manual (1963)" and "AWWA Manual M5, Water Utility Management (1959)". However, the Outlined Schedule of Accounts which follows gives the general classification headings and organization of accounts.

OUTLINED SCHEDULE OF ACCOUNTS

Balance Sheet Accounts

Assets and Other Debits	Liabilities and Other Credits
Plant and equipment	Long term debt
Construction work in progress	Short term debt
Invested and special funds	Current & accrued liabilities
Current and accrued assets	Deferred credits
Deferred debits	Reserves
	Surplus

Income Accounts

Revenues	Expenditures & Income Deductions
Sales of water	Source of supply expenses
Other revenues	Pumping expenses
	Water treatment expenses
	Transmission and distribution expenses
	Customer's accounting expenses
	Administrative and general expenses

Revenues	Expenditures & Income Deductions
	Taxes
	Miscellaneous unclassified expenses
	Depreciation
	Income deductions
	Balance of income

Most of the accounts represent detailed breakdown of these general classification headings; see the references listed just above.

8.3.0 Customer Relations(VIII-5)

By its very nature, every public water utility has public relations, but if the utility is aware of its customer relations, they are most likely to be good. The task is to develop an informed public. Employees should be informed themselves on utility programs and activities, and they should be guided or trained to the task of informing the public. All means of disseminating information in the community should be utilized. All reports concerning the water system should be available to the public.

Public water utilities should adopt a policy concerning home treatment units.

8.3.1 Management

The job of building public relations should start at the top. Management should be convinced that activities to promote good will are worthwhile. Management is also responsible for developing a sound base for this good will by fostering positive programs aimed at providing the best possible water service.

8.3.2 Setting the Objective

The ultimate objective is a public that is informed concerning the policies, practices, and problems of its water utility, so that it will understand the utilities requirements and appreciate the wisdom of attending to them. This requires a constant, organized, intelligent effort using every available means of communication to tell the story of water supply. The value of water in health, in industrial and agricultural production, and in many other ways provides an unending source of interesting information. The place of the water system in local history is a theme of interest to students and others in the community.

8.3.3 Internal Action

No customer relations program can be successful unless the water utility is doing the best possible job with the available resources, for the light of public interest shows up defects more clearly than it does good points.

8.3.3.1 Review of Existing Policies

A first step is to review all utility policies and practices in terms of their public relations impact. This would include the procedures for establishing new accounts to make them as convenient as possible for the customer. It would include review of the equity of water rates, the attitude and conduct of meter readers in their contacts with customers, and billing practices. Attention should be given to the handling of complaints and requests for information. The methods of making installations and repairs and performing maintenance work should be examined with a view to public convenience. Water quality is a direct line of communication with each and every customer, and attention must be given to aesthetic considerations such as taste, odor, color, and clarity as well as health factors. The attitude of personnel toward the public is of paramount importance. Employees should remember that their job is to serve the public, not to direct it.

8.3.3.2 Establishing New Policy

Every proposed new policy should be examined in terms of its possible public or customer reaction before it is adopted. A change in phrasing or a minor difference in approach can often make a major difference in making a seemingly harsh policy understandable and acceptable.

8.3.4 External Action

Action outside the regular scope of water utility operations is important too because it is taken specifically for the purpose of improving public relations. It is what most people think of first in public relations - publicity and advertising, or selling the program. Public relations is a never-ending job which should become a way of life for every staff member to ensure success.

8.4.0 Emergency Plans of Action(VIII-4)

8.4.1 Desirable Scope

The management and operation of water utilities is directed toward guaranteeing a continuous, uninterrupted supply of high quality water to users. Water purveyors have a good record of maintaining quantity and quality under the most adverse conditions. However, disruptions in water supply do occur, and quality impairment has been recorded under certain conditions. A greater awareness by water utility managers of natural and nuclear disasters, and civil disorders and their potential effects on water systems could produce a schedule of design, operation, and maintenance which would greatly reduce their effects on water utility operations. The State should review and approve plans for emergency action.

Natural disasters which could affect water supplies include: tornado, hurricane, earthquake, tidal wave, fire, landslides, and fallout of volcanic dust.

Other disasters which could affect water supplies include: bomb blast, incindiary fire, flood, riot, civil disorder, vandalism, explosion, biological warfare, nuclear fallout, industrial waste discharge, and spills of oil and hazardous materials.

Water suppliers should be aware of the emergency notification requirements of the EPA Interim Primary Drinking Water Standards of March 14, 1975 and make plans for compliance in the event it becomes necessary.

8.1.2 Disaster Effects

The potential effects of disasters on water utilities include: plant (structural) damage, reservoir damage, storage tank damage, broken mains, watershed damage, contamination, power outages, communication disruption, transportation failure, and employee shortages.

8.4.3 Vulnerability Assessment

In assessing the vulnerability of a specific water system to an assumed type of disaster the following steps should be taken: (1) identify and describe water system components; (2) assign design characteristics to the assumed disaster (such as flood levels, wind velocity, magnitude of earthquake, etc.); (3) estimate the effects of the design disaster on each water system component, and tabulate; (4) estimate water demand, both quantity and quality, during and after the disaster; (5) determine the probable operational capability of the water system to meet the estimated requirements; and (6) if it appears that the system cannot meet the water requirements, identify the primary reasons for failure.

This type of analysis can be performed for a variety of design disasters which are likely to occur in a given area.

8.4.4 Protective Measures

There are many steps that can be taken to protect water utilities against disaster effects, ranging from design considerations to action taken prior to, during and after a disaster. Consider use of several small chlorine containers in lieu of 30-55 ton tank cars to reduce risk to the public and of plant outages.

Some protective measures are: alternate sources of water such as wells; water storage on or off the system in covered or potable tanks; monitoring, detection, and identification of contaminating substances; dilution; long-term reservoir detention; water intake at varying reservoir depths; availability of standby electric generators; alternate fuel sources; auxiliary engine drives; arrangements with electric utility for high priority maintenance or restoration of power to water facilities during emergencies; inventory available portable electric generators and pumps; stockpile basic materials such as chemicals, chlorine, and critical spare parts; stockpile food for confined employees; availability of special purpose transport, such as four-wheel-drive vehicles, water distribution trucks, and helicopters; plan for use of secondary roads in the event main roads are blocked; adequate structural design of reservoirs and tanks; automatic valves to close and isolate main breaks; protection for operating personnel; two-way radio; and arrangements with police, highway patrol, or ham radio operators for emergency communications.

8.4.5 Emergency Operations Planning

An emergency operations plan should describe the mission and how to use resources to accomplish the mission. It should be as concise as possible, and not overly detailed. An emergency plan can be developed in the following steps: (1) state assumptions of emergency caused effects; (2) estimate remaining capabilities; (3) estimate community requirements; (4) match capabilities to requirements; (5) specify priorities; (6) program best way to use resources; (7) assign specific tasks to assumed surviving personnel.

Water treatment equipment suppliers should include emergency operating instructions with all equipment. This will enable the consulting engineer to incorporate this information as he prepares the operation and maintenance manual. Also, the consulting engineers, using emergency equipment instructions, may make an evaluation of equipment with regard to flexibility during emergencies. An evaluation of this type will allow plant personnel to respond more efficiently to emergencies affecting the equipment.

8.4.6 Making and Implementing an Emergency Operations Plan

The main considerations in making and implementing an emergency operations plan are: (1) inventory organization and make assignments; (2) make vulnerability assessment; (3) set priorities and program best use of resources; (4) provide personnel protection; (5) inventory communications equipment and plan emergency usage; (6) assess protection of plant equipment, inventories, and records; (7) initiate mutual-aid and other cooperative agreements; (8) determine emergency-phase action steps; (9) plan post-disaster operational recovery operations; and (10) plan improvement of system as indicated by deficiencies.

8.4.7 Security

Security should be emphasized as a part of emergency operations planning. Someone should be appointed as a Security Director. The duties should include: (1) advise management on the problems of vandalism; (2) provide law-enforcement liason; (3) make employee security checks; (4) make vulnerability assessment; (5) assume civil defense responsibilities; (6) handle bomb threats; and (7) be responsible for issuance and control of identification cards.

SECTION VIII OPERATION AND MAINTENANCE

RATIONALE FOR OPERATION & MAINTENANCE STANDARDS

8.1.0 Operation and Maintenance Program

Modern equipment and procedures are not enough to produce high quality water service, the people who use them should be qualified and efficient. Qualified personnel are the key to good operation and maintenance. Earlier Sections of these Standards are aimed at securing the physical facilities needed to produce an ample supply of safe water. This Section seeks to set Standards for proper operation and maintenance of these facilities by water system personnel.

8.1.1 Supervision

It is essential that the person in charge of water system operations be fully qualified by education, training, and experience to direct such activities. That person should have all of the necessary knowledge and skill required to make the system perform as it should, both under normal and under emergency conditions.

8.1.1.1 Number and Types of Staff

Detailed guidelines regarding staffing of various water system operations are given in Section X of this Manual.

8.1.1.2 Delegation of Responsibility

One means for clear delegation of authority is by means of a general organization chart which shows the relationship between all supervisory employees of a utility. Additional charts can be used to outline specific duties and to define the relationship between all employees in various divisions. Once authority is delegated, it must be recognized and respected by every member of the staff.

Understanding of an employee's authority and duties can avoid operational failures which can occur if they are vague or undefined.

8.1.2 Analyses and Records

The records recommended by these Standards are minimum, involving only those necessary to demonstrate compliance with the Federal Drinking Water Standards. Overall system requirements in this regard are presented and discussed in more detail in Section IX of this Manual.

8.1.2.1 Annual Summary

The annual summary recommended here is valuable not only in evaluating post performance of the system, but also in anticipating future needs of the system.

8.1.3 Public Notification of Variances, Exemptions, and Non-Compliance with EPA Interim Primary Drinking Water Standards of March 14, 1975.

The material in this Section is taken directly from the new Standards.

8.1.4 Water Utility Action Required for Non-Compliance with EPA Interim Primary Drinking Water Standards of March 14, 1975.

The Rationale for these requirements is given in the IPS as published.

8.1.5 Operating Practice Manual

This type of manual is an excellent way, and perhaps the only way, for engineering designers and equipment suppliers to transmit and convey all of the information which they have about the water system to all persons who operate, or will operate in the future, the facilities which they have produced for the operators' use.

8.1.5.1 Operator Training

A background in engineering, chemistry, biology, or other formal education can be very useful in many water system jobs. However, regardless of the extent of a water employee's formal training, some in-service, hands-on training is an absolute necessity. Here, the Operating Practice Manual for the particular water works in question is an indispensable aid, and can be the basis for one in-service training course. On the job training for a constant increase in the acquisition of ability and knowledge is a joint responsibility of both employer and employee. If the employer is willing to pay employees for time spent in keeping abreast of water technology it greatly increases the importance of such training in the eyes of employees.

The subject of personnel training is discussed in detail under Section X of this Manual.

8.1.6 Operating Well Pumps

Continuous pump operation is preferable to intermittent operation for two reasons; power savings and reduced backwashing action in the well. Every time a pump starts, water must be lifted from the level of water in the well to the level of the discharge check valve, then, when the pump stops the water behind the check valve drains back into the well with a waste of power. If pump cycling is infrequent this is a minor loss, but the loss can be significant with very short cycles of operation. In sand formations, the backflow of water into the well upon pump stoppage can flush fine sand through slotted pipe casings. With the use of properly sized screens rather than slotted pipe and with proper well development, this hazard of fine sand entering the well can be minimized.

The need for start-stop cycles of pumps can be controlled by proper sizing of well pumps with respect to demands placed on them, by providing peaking storage on the system, and by use of a pressure regulating valve in the discharge line from the well pump (the power waste from use of the pressure regulating valve is frequently less than the power loss from frequent off-on operation).

8.1.7 Pump Operation Checks

As mentioned in the Standards for this Section, the basis for making the pump operational checks and related information will be found in "AWWA Manual M8, Water Distribution Training Course".

8.1.8 Basin Operations

The accumulation of organic matter in settling basins can interfere with settling and produce tastes and odors in the water, hence the need for continuous removal.

8.1.9 Operation of Chemical Feeders

Controlling chemical feed to a plus or minus 3 per cent as provided by these Standards is recommended to obtain best treatment results and to minimize waste of chemicals.

8.1.10 Filter Operation

As referred to in these Standards there are at least ten major potential problems requiring operator attention if filters are to perform their important treatment functions and if filter failures are to be avoided.

Problems in filter operation and performance can arise either from poor design or poor operation. However, during the past 10 years the tremendous advances in engineering design of filters and filter controls and appurtenances have made water filtration an inherently stable, extremely efficient, and highly reliable unit treatment process. With proper design and good operation, all the problems of the past are easily solved.

Some potential filter problems are listed below:

1. Surface clogging and cracking.
2. Short runs due to rapid increases in headloss.
3. Short runs due to floc breakthrough and high effluent turbidity.
4. Variations in effluent quality with changes in applied water flow rate or quality.
5. Gravel displacement or mounding.
6. Mud balls.
7. Growth of filter grains, bed shrinkage, and media pulling away from sidewalls.
8. Sand leakage.
9. Loss of media.
10. Negative head and air binding.

Some solutions to these problems are suggested below:

1. Surface clogging and cracking are usually caused by rapid accumulations of solids on the top surface of the fine media. This is not a problem in dual or mixed-media filters because of the greater porosity of their top surface as compared to sand. Also, when a filter aid is used with dual or mixed-media, the dosage can be reduced as necessary (or eliminated) which allows particulates to penetrate deeper into the bed. In other words, regulation of the polymer dosage to the filter influent gives some control over the effective porosity of the filter so as to accommodate changes in incoming floc characteristics.

2. Short runs due to rapid increases in headloss are related to the problem just discussed in that dual and mixed-media beds collect particulates throughout the depth of the bed rather than mostly at the surface of the bed, as with a sand or other surface type filter, and are much less susceptible to this problem. Also the flexibility provided by use of a polymer as a filter aid allows control of the rate of headloss buildup by dosage changes.

3. Short filter runs due to floc breakthrough can be avoided by using mixed-media. As mentioned earlier, this is one very important point of superiority of mixed-media over dual media and sand filters. It arises because of the much greater surface area of the grains in a mixed-media filter as compared to sand or dual media. The finest media in a mixed-media bed is 40 to 80 mesh (10 percent of total bed), 40 to 50 mesh (9 percent of total) in a sand bed, and 40 to 50 mesh (5 percent of total) in a dual media filter. The finest media (garnet) in a mixed-media bed has the advantage not only of being finer but

also in being located at the very bottom of the filter where the applied load is lightest and where it can serve its intended purpose as a polishing agent. Floc storage depths above the finest media in various typical beds are as follows: sand, 0 cm (0 in.); coal-sand, 46 cm (18 in.); and mixed-media, 69 cm (27 in.). A further advantage of mixed media in this regard lies in the greater total number of media particles contained in an equal volume of bed.

This tremendously increases the number of opportunities for contact between media and colloids in the water which greatly enhances removal of these colloids.

4. Variation in effluent quality with changes in applied water are much less in mixed-media beds which are much less affected either by changes in flow or influent quality than either sand or dual media. Again this relates to the greater total surface area of the fine media, the greater total number of fine media particles, and the smaller size of pore openings at the bottom of the filter bed.

5. Gravel displacement or mounding can be eliminated by use of the 7 cm. (3 in.) layer of coarse garnet or ilmenite between fine media and gravel supporting bed, and by limiting the total flow and head of water available for backwash (that is, not drawing wash water from a high pressure source through a pressure reducing valve which could fail).

6. Mud ball formation can be eliminated by providing an adequate backwash flow rate, and a properly designed system for auxiliary scour (surface wash). The successful use of beds employing filter aids and in-depth filtration is dependent on provision and operation of a good system of auxiliary scour.

7. Growth of filter grains, bed shrinkage, and media pulling away from filter sidewalls are related problems. Again, the provision and use of adequate backwash facilities including surface wash are the keys. It is the compressibility of filter grains which are heavily coated with materials filtered, deposited, or absorbed from the water which is the root of these difficulties.

   With one exception, to be discussed later, these problems can be avoided by proper backwashing. It should be mentioned that this growth of particles refers to a macroscopic increase in size and not to the development of a microscopic film of polymer and other chemicals which result from proper use of a filter aid and which is beneficial in adsorption and retention of particulates for the period of a single operational cycle in the use of dual and mixed-media beds and which is not nearly thick enough to be a problem by increasing the compressibility of the bed. Actually in the one exception alluded to earlier which is calcium carbonate deposition on filter grains, an alum or polymer film on filter grains may actually be an aid in reducing the adherence of calcium carbonate and facilitating its removal during backwashing. However, in any case, in filtering lime softened waters it is important to adjust the pH of filter influent by addition of carbon dioxide or acid to a level at which calcium carbonate deposition does not occur.

8. Sand leakage can be prevented by using the coarse garnet layer between the fine media and gravel supporting bed as recommended earlier, as this prevents the downward migration and escape of fines.

9. Loss of media, particularly of coal during backwashing, is one problem for which there is no complete solution. Losses can be reduced by increasing the distance between the top of the expanded bed during maximum backwash flows and the wash water troughs. It also can be helped by cutting off air wash or auxiliary scour 1 or 2 minutes before the end of the main backwash.

10. Negative head and air binding can be avoided in most cases, but there may be a few extreme situations, usually of short duration, where they cannot be entirely eliminated. In any case it is a good idea to provide a water depth of at least 1.5 M (5 ft.) above the surface of the unexpanded filter bed. The more depth the better, so far as negative head and air binding are concerned.

When filter influent water contains dissolved oxygen at or near saturation levels, and when pressure is reduced to less than atmospheric below the surface of the fine media by siphon action, the oxygen comes out of solution and gas bubbles are released. They may accumulate within the bed and tremendously increase the resistance to flow or head loss. When flow through a filter is stopped and the water level is lowered in preparation for backwashing, bed pressures are reduced and more oxygen is released. Even further release of bubbles occurs during backwash which may lead to loss of media in the waste backwash water when bubbles adhere to coal or sand and carry them into the wash water troughs. More frequent filter backwashing may alleviate the problem to some extent as there is then less time for bubbles to accumulate, but when the problem is acute, as it may be in the spring when surface water is warming (and oxygen solubility is decreasing at the higher temperatures) it is a problem which under the very worst conditions may only be endured and not solved. Maintaining maximum water depths above the beds and frequent backwashing may help but may not completely eliminate the difficulties.

8.1.11 Operation of Finished Water Tanks and Reservoirs

The checks of physical facilities recommended by the Standards is to insure that there are no failures which would reduce the effectiveness of safeguards originally provided. The removal of sediment from reservoirs protects against development of taste and odor and aids in preventing localized corrosion of steel.

8.1.12 Operation of Distribution Systems

There are several benefits to the maintenance of free residual chlorine of 0.2 mg/l in all parts of the distribution system. It prevents regrowth of bacteria and controls slime growths on pipe surfaces. It aids in preventing the development of anaerobic conditions in pipelines and the growth of iron and sulfate-reducing bacteria which might otherwise thrive. It provides some protection against minor amounts of contamination entering the system through back-siphonage or cross-connection, but, more importantly, the disappearance of chlorine residuals in certain parts of the system is a valuable tool in locating these sources of contamination.

In well-designed water distribution systems, main flushing may not be necessary, but in systems with poor circulation and particularly those with many dead-end lines, frequent flushing may be necessary to prevent red-water conditions and customer complaints.

At any time that it is necessary to cut into a pipeline, it is wise to observe any indications of corrosion, deposition, or sediment accumulation. This is the proof of the effectiveness of measures taken in treatment for stabilization of the water. Better yet, provisions can be made to place metal coupons in various spots in the distribution system which can be removed and weighed for gain or loss in weight to determine corrosion or deposition actions which may be taking place. Means for making and interpreting the results of coupon tests are given in AWWA, "Quality Goals for Public Water", JAWWA, p. 1317, 1968.

8.1.12.1 Main Disinfection

In laying or repairing water mains it is difficult or impossible to avoid any possibility of contamination, so that flushing and disinfection are absolutely necessary.

8.1.12.2 Pipe Joints

There have been many instances where troublesome bacteria growth have occurred in jute and hemp joint packing which have not been entirely overcome by disinfection, hence the prohibition against use of these materials.

8.1.12.3 Negative Pressure

Negative pressure in pipelines entail the hazard of introducing outside foreign materials into the system and thus must be avoided.

8.1.12.4 Cross-Connection Control

The reasons for cross-connection control programs are fully described in the "EPA Cross-Connection Control Manual, 1974".

8.1.13 Treatment Chemicals and Other Supplies

To avoid interruptions to water service or proper treatment it is essential to have a system for acquisition of the necessary supplies which takes into account contingencies as well as normal conditions.

8.1.14 Maintenance Program

The need for a formal systematic program of preventative maintenance to proper system operation has been demonstrated by virtually every water system in existence, either in a positive or a negative way.

8.1.14.1 through 8.1.14.9

These are mainly housekeeping and general sanitation reminders.

8.2.0 Budgeting and Financial Planning

Proper budgeting and long range financial planning are the heart of water system operation and the keys to success or failure, so that any discussion of water works operation must direct attention and provide some general guidance in these matters if it is to be complete.

8.3.0 Customer Relations

Customer relations usually are a good indicator of the kind of service the water utility is providing. Good customer relations cannot be maintained for very long without continuous good performance by the utility, even with the best of public relations programs. On the other hand, even with the best operated system, the public must be informed by a conscious public relations effort of the facts if maximum public support, particularly in the financing of operations and improvements, is to be obtained.

8.4.0 Emergency Plans of Action

In reviewing the types of emergencies which can affect water works operations as presented in these Standards, it is apparent that their nature is such that advance preparation and planning are essential. There simply is not time under most emergency conditions to both plan and take the necessary corrective measures. The planning must be done, in a general way at least, prior to the emergency. The Standards point out of suggest a wide variety of emergencies which require advance consideration, planning, and acquisition of equipment, materials, and supplies, as well as advance training, organization, and other preparation of personnel. The omission of these items would seem inappropriate in any complete discussion of water systems.

Failure to meet the new EPA IPS requires certain emergency action by the water supplier, as described in the IPS.

SECTION IX SURVEILLANCE

SUMMARY OF SURVEILLANCE STANDARDS

9.1.0 Surveillance(II-71)(II-72)

Each water utility should develop and implement such surveillance plans as are necessary to obtain and assure delivery of water to its consumers which complies in all respects with the Federal Drinking Water Standards and local and State laws, rules, and regulations. The State should approve all surveillance plans. Surveillance by each water utility should include: (1) regular sanitary surveys of the point of intake, treatment plant, storage reservoirs, and distribution system with correction of defects and deficiencies; (2) establishment of a program approved by the State for the detection and elimination of cross-connections; (3) regular collection of water samples from the source of supply, the treatment process, storage reservoirs, and smooth nose taps on various parts of the distribution system to meet schedules set forth in the Federal Drinking Water Standards and to meet local and emergency needs; (4) analysis of samples as required to measure the chemical, biological, physical, and radiological quality of the water to be compared to the Federal Drinking Water Standards and local and State requirements; (5) adequate operational control testing; and (6) provision for use of approved laboratory facilities.

9.2.0 Responsibility(VIII-5)(IX-5)

Responsibility for the conditions in the water supply system are held by: (1) the water utility from the point of intake to the point of connection of the customer's service piping; and (2) the owner of the property served and the municipal county, or other authority having legal jurisdiction from the point of connection to the customer's piping to the free-flowing outlet.

9.3.0 Source and Facilities Surveillance(II-71)(II-72)

9.3.1 Reliability of System

The water utility and/or owner of the property served, to the extent of their respective jurisdictions, should provide and maintain conditions through the entirety of the water supply system in a manner which will assure a high degree of capability and reliability to effect compliance with these Standards. This requirement should pertain to the source of supply, treatment, transmission, storage and distribution facilities, and the operation thereof. In addition, this should include specific and continuing assessment of the capability, effectiveness, and reliability of the treatment process in

Preceding page blank

relation to potential contaminants in the source of supply. This should also include the identification and evaluation of all factors having potential for impairing the quality of the water as delivered to the consumers; the elimination of hazards; and the provisions of appropriate preventive and control measures.

9.3.2 Source

Selection of sources of supply which present minimal risks of contamination from wastewaters and which contain a minimum of impurities that may be hazardous to health is preferred. In all cases, sources should be selected and maintained on a basis which will assure that the water is continuously amenable to available treatment processes. Every effort should be made by the utility and State to the extent of his jurisdiction, to prevent degradation of quality of water supply sources.

9.3.2.1 Surveys

Surveys should be made of the source by the utility in preliminary investigations to locate and identify health hazards. These sources should be monitored for those parameters of quality for which treatment is or reasonably may be required and adequate source protection should be provided. Sampling frequency shall conform to the requirements of the IPS.

The monitoring program should be established by the water utility and approved by the State. Appropriate procedures shall be established by the State for emergency situations, such as upstream sewage by-passes, to assure provision of any necessary adjustments to sources or treatment or to provide for public notification. See Section 8.4.0 for procedures.

9.3.3 Treatment

The utility shall provide treatment which will assure a high degree of reliability in effecting compliance with these Standards. In general, this requires disinfection of all waters and, in addition, coagulation, with or without settling, and filtration or equivalent of all surface waters. If the water purveyor has data acceptable to the State indicating that the produced water will consistently meet the Federal Drinking Water Standards, the above requirements for treatment may be reduced as determined by the State.

9.3.4 Water Supply Systems

Frequent general sanitary surveys should be made of water supply system by appropriate authority to locate and identify health hazards that exist in the system. The manner and frequency of making these surveys, and the rate at which discovered health hazards are to be removed, shall be in accordance with a program approved by the State. General sanitary surveys are not to be confused with specific sampling and analysis requirements of the IPS.

9.3.5 Sampling Taps

Smooth-nose sampling taps must be provided for the collection of representative samples for both bacteriological and chemical analyses.

9.4.0 Sampling Frequency

9.4.1 Microbiological Contaminant Sampling and Analytical Requirements (II-72)

a. The supplier of water shall make coliform density measurements in accordance with the analytical recommendations set forth in "Standard Methods for the Examination of Water and Wastewater", American Public Health Association, 13th Edition, pp 662-688, except that only a 100 mililiter sample size shall be employed in the membrane filter technique. The samples shall be taken at points which are representative of the conditions within the distribution system.

b. The supplier of water shall take coliform density samples at regular intervals throughout the month, and in number proportionate to the population served by the public water system. In no event shall the frequency be less than as set forth below:

Population served:	Minimum number of samples per month:
25 to 2,500	2
2,501 to 3,300	3
3,301 to 4,100	4
4,101 to 4,900	5
4,901 to 5,800	6
5,801 to 6,700	7
6,701 to 7,600	8
7,601 to 8,500	9
8,501 to 9,400	10
9,401 to 10,300	11
10,301 to 11,100	12
11,101 to 12,000	13
12,001 to 12,900	14
12,901 to 13,700	15
13,701 to 14,600	16
14,601 to 15,500	17

Population served:	Minimum number of samples per month:
15,501 to 16,300	18
16,301 to 17,200	19
17,201 to 18,100	20
18,101 to 18,900	21
18,901 to 19,800	22
19,801 to 20,700	23
20,701 to 21,500	24
21,501 to 22,300	25
22,301 to 23,200	26
23,201 to 24,000	27
24,001 to 24,900	28
24,901 to 25,000	29
25,001 to 28,000	30
28,001 to 33,000	35
33,001 to 37,000	40
37,001 to 41,000	45
41,001 to 46,000	50
46,001 to 50,000	55
50,001 to 54,000	60
54,001 to 59,000	65
59,001 to 64,000	70
64,001 to 70,000	75
70,001 to 76,000	80
76,001 to 83,000	85
83,001 to 90,000	90
90,000 to 96,000	95
96,001 to 111,000	100
111,001 to 130,000	110
130,001 to 160,000	120
160,001 to 190,000	130
190,001 to 220,000	140
220,001 to 250,000	150
250,001 to 290,000	160
290,001 to 320,000	170
320,001 to 360,000	180
360,001 to 410,000	190
410,001 to 450,000	200
450,001 to 500,000	210
500,001 to 550,000	220
550,001 to 600,000	230
600,001 to 660,000	240
660,001 to 720,000	250
720,001 to 780,000	260
780,000 to 840,000	270
840,001 to 910,000	280
910,001 to 970,000	290

Population served:	Minimum number of samples per month:
970,001 to 1,050,000	300
1,050,001 to 1,140,000	310
1,140,001 to 1,230,000	320
1,230,001 to 1,320,000	330
1,320,001 to 1,420,000	340
1,420,001 to 1,520,000	350
1,520,001 to 1,630,000	360
1,630,001 to 1,730,000	370
1,730,001 to 1,850,000	380
1,850,001 to 1,970,000	390
1,970,001 to 2,060,000	400
2,060,001 to 2,270,000	410
2,270,001 to 2,510,000	420
2,510,001 to 2,750,000	430
2,750,001 to 3,020,000	440
3,020,001 to 3,320,000	450
3,320,001 to 3,620,000	460
3,620,001 to 3,960,000	470
3,960,001 to 4,310,000	480
4,310,001 to 4,690,000	490
4,690,000	500

c.

1. When the coliform colonies in a single standard sample exceed four per 100 milliliters, daily samples shall be collected and examined from the same sampling point until the results obtained from at least two consecutive samples show less than one coliform per 100 milliliters.

2. When organisms of the coliform group occur in three or more 10 ml portions of a single standard sample, daily samples shall be collected and examined from the same sampling point until the results obtained from at least two consecutive samples show no positive tubes.

3. When organisms of the coliform group occur in all five of the 100 ml portions of a single standard sample, daily samples shall be collected and examined from the same sampling point until the results obtained from at least two consecutive samples show no positive tubes.

4. The location at which the check sample was taken pursuant to paragraphs (c) (1), (2) or (3) of this section must not be eliminated from future sampling

because of a history of questionable water quality. Check samples shall not be included in calculating the total number of samples taken each month.

d. When a particular sampling point has been confirmed, by the first check sample examined as directed in paragraphs (c) (1), (2), or (3) of this section, to be in non-compliance with the maximum contaminant levels, the supplier of water shall notify the State.

e. When the maximum contaminant levels are exceeded as confirmed by check samples taken pursuant to paragraph (c) (1), (2), or (3) of this section, the supplier of water shall report as directed in Section 8.1.3.

f. When a particular sampling point has been shown to be in non-compliance, water from that location shall be retested within one hour. If the non-compliance is confirmed, the State shall be notified. Also, if the non-compliance is confirmed, a sample for coliform analysis must be immediately collected from that sampling point and the results of such analysis reported to the State.

g. Standard bacteria, plate count samples shall be analyzed in accordance with the recommendation set forth in "Standard Methods for the Examination of Water and Wastewater", American Public Health Association, 13th Edition, pp 660-662. Samples taken for the purpose of plate count analysis shall be collected at points which are representative of conditions within the distribution system at a frequency at least equal to 10 percent of the frequency for coliform analysis as directed in paragraph (b) of this section with the exception that at least one sample shall be collected and analyzed monthly.

9.4.1.1 Substitution of Residual Chlorine Measurement for Total Coliform Measurement (II-72)

a. The supplier of water may, with the approval of the State, substitute the use of chlorine residual monitoring for not more than 75 percent of the samples required to be taken, provided that the supplier of water takes chlorine residual samples at points which are representative of the conditions within the distribution system at the frequency of at least four for each substituted microbiological sample. There shall be at least daily determinations of chlorine residual. Measurements shall be made in accordance with "Standard Methods", 13th Edition, pp 129-132. When the supplier of water exercises the option provided in this paragraph (a), he shall maintain no less than 0.2 mg/l free chlorine in the public water distribution system.

b. For public water systems serving 4900 or fewer persons, the supplier may, with the approval of the State, make a total substitution of chlorine residual measurement for the samples required to be taken, provided, that the supplier of water takes chlorine residual samples at points which are representative of the conditions within the distribution system at the rate of one per day for each microbiological sample required to be taken per month.

When the supplier of water exercises the option provided by this paragraph (b) he shall maintain no less than 0.3 mg/l free chlorine in the public water distribution system. Measurements shall be made in accordance with "Standard Methods", 13th Ed., pp 129-132.

9.4.1.2 Laboratory Certification(II-72)

For the purposes of determining compliance with IPS, samples may be considered only if they have been analyzed by a laboratory approved by the State. The approval shall be contingent upon maintenance of proper laboratory methods and technical competence and upon the retention for inspection at reasonable times of analytical results. Approved laboratories shall make periodic reports as required by the State.

9.4.2 Turbidity Sampling And Analytical Requirements(II-72)

1. Samples shall be taken at a representative entry point(s) to the water distribution system at least once per day (at least once per month for supplies using water obtained from underground sources) for the purpose of making turbidity measurements. The measurement shall be made in accordance with the recommendations set forth in "Standard Methods for the Examination of Water and Wastewater", American Public Health Association, 13th Edition, pp. 350-353 (Nephelometric Method).

2. In the event that such measurement indicates that the maximum allowable limit has been exceeded, the sampling and measurement shall be repeated within one hour. The results of the two measurements shall be averaged, and if the average confirms that the maximum allowable limit has been exceeded, this average shall be reported as directed in 8.4.0. If the monthly average of all samples

exceeds the maximum allowable limit, this fact shall be reported as directed in 8.1.3.

3. The requirements of this section shall not apply to public water systems other than community water systems which use water obtained from underground sources.

9.4.3 Inorganic Chemical Sampling And Analytical Requirements(II-72)

1. To establish an initial record of water quality, an analysis shall be completed for all community water systems utilizing surface water sources within one year following the effective date of this subpart. This analysis shall be repeated at yearly intervals.

2. An analysis for community water systems utilizing groundwater sources shall be completed within two years following the effective date of this subpart. This analysis shall be repeated at three-year intervals.

3. Analyses for public water systems other than community water systems, whether supplied by surface or ground water sources, shall be completed within six years following the effective date of this subpart. These analyses shall be repeated at five-year intervals.

4. If the supplier of water determines or has been informed by the State that the level of any contaminant is 75 percent or more of the maximum contaminant level, he shall analyze for the presence and quantity of that contaminant at least once per month following the initial analysis or information. If, after conducting monthly testing for a period of at least one year, the supplier of water demonstrates to the satisfaction of the State that the level of such contaminant is stable and due to a natural condition of the water source, he may reduce the frequency of analysis for that contaminant consistent with the requirements of paragraph (3) of this section.

5. If the supplier of water determines or has been informed by the State that the level of any contaminant exceeds the maximum contaminant level for the substance, he shall confirm such determination or information by repeating the analysis within 24 hours following the initial analysis or information, and then at least at weekly intervals during the period of time the maximum contaminant level for that substance has been exceeded, or until a monitoring schedule as a condition to a variance, exemption or enforcement action shall become effective. The results of such repetitive testing shall be averaged and reported as prescribed in paragraph (6) of this section.

6. To judge the compliance of a public water system with the maximum contaminant levels listed, averages of data shall be used and shall be rounded to the same number of significant figures as the maximum contaminant level for the substance in question. Each average shall be calculated on a past 12-month moving average basis if less than twelve samples per year are analyzed, and on a past three month moving average basis if twelve or more samples per year are analyzed. In cases where the maximum contaminant level has been exceeded in any one sample, the average concentration shall be calculated on a one-month moving average basis and reported pursuant to 8.4.0. If the mean of the samples comprising the one month moving average exceeds the maximum contaminant level, the supplier of water shall give public notice pursuant to 8.1.3.

7. The provisions of paragraphs (5) and (6) of this section notwithstanding, compliance with the maximum contaminant level for nitrate shall be determined on the basis of individual analyses rather than by averages. When a level exceeding the maximum contaminant level for nitrate is found, the analyses shall be repeated within 24 hours, and if the mean of the two analyses exceeds the maximum contaminant level, the supplier of water shall report his findings pursuant to 8.4.0, and 8.1.3.

8. Analyses conducted to determine compliance shall be made in accordance with the following methods:

   a. Arsenic - Atomic Absorption Method, "Methods for Chemical Analysis of Water and Wastes", pp. 95-96, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C., 20460, 1974.

   b. Barium - Atomic Absorption Method, "Standard Methods for the Examination of Water and Wastewater", 13th Edition, pp. 210-215, or "Methods for Chemical Analysis of Water and Wastes", pp. 97-98. Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

   c. Cadmium - Atomic Absorption Method, "Standard Methods for the Examination of Water and Wastewater", 13th Edition, pp. 210-215, or "Methods for Chemical Analysis of Water and Wastes", pp. 101-103, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

   d. Chromium - Atomic Absorption Method, "Standard Methods for the Examination of Water and Wastewater", 13th Edition, pp. 210-215, or "Methods for Chemical Analysis of Water and Wastes", pp. 105-106, Environmental

Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

e. Cyanide - Titration or colorimetric Methods, "Methods for Chemical Analysis of Water and Wastes", pp. 40-48, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

f. Lead - Atomic Absorption Method, "Standard Methods for the Examination of Water and Wastewater", 13th Edition, pp. 210-215, or "Methods for Chemical Analysis of Water and Wastes", pp. 112-113, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

g. Mercury - Flameless Atomic Absorption Method, "Methods for Chemical Analysis of Water and Wastes", pp. 118-126, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

h. Nitrate - Brucine Colorimetric Method "Standard Methods for the Examination of Water and Wastewater", 13th Edition, pp. 461-464, or Cadmium Reduction Method, "Methods for Chemical Analysis of Water and Wastes", pp. 201-206, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

i. Selenium - Atomic Absorption Method, "Methods for Chemical Analysis of Water and Wastes", p. 145, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

j. Silver - Atomic Absorption Method, "Standard Methods for the Examination of Water and Wastewater", 13th Edition, pp. 210-215, or "Methods for Chemical Analysis of Water and Wastes", p. 146, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

k. Fluoride - Electrode Method, "Standard Methods for the Examination of Water and Wastewater", 13th Edition, pp. 172-174, or "Methods for Chemical Analysis of Water and Wastes", pp. 65-67, Environmental Protection Agency, Washington, D.C. 20460, 1974, or Colorimetric Method with Preliminary Distillation, "Standard Methods for the Examination of Water and Wastewater", 13th Edition, pp. 171-172 and 174-176, or "Methods for Chemical Analysis of Water and Wastes", pp. 59-60, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

9.4.4 Pesticide and Organic Chemicals Sampling and Analytical Requirements (II-72)

1. To establish an initial record of water quality, an analysis of substances for the purpose of determining compliance shall be completed for all community water systems utilizing surface water sources within one year following the effective date of this subpart. This analysis shall be repeated at yearly intervals.

2. An analysis for community water systems utilizing ground water sources shall be completed within two years following the effective date of this subpart. This analysis shall be repeated at three-year intervals.

3. Analyses for public water systems other than community water systems, whether supplied by surface or ground water sources, shall be completed within six years following the effective date of this subpart. These analyses shall be repeated at five-year intervals.

4. If the supplier of water determines or has been informed by the State that the level of any contaminant is 75 percent or more of the maximum contaminant level, he shall analyze for the presence and quantity of that contaminant at least once per month following the initial analysis or information. If, after conducting monthly testing for a period of at least one year, the supplier of water demonstrates to the satisfaction of the State that the level of such contaminant is stable and due to a natural condition of the water source, he may reduce the frequency of analysis for that contaminant consistent with the requirements of paragraph (a) of this section.

5. If the supplier of water determines or has been informed by the State that the level of contaminants exceeds the maximum contaminant level, he shall confirm such determination or information by repeating the analyses within two weeks following the initial analysis or information. The average of the two analyses, if in excess of the maximum contaminant level, shall be reported as directed in 8.4.0 and 8.1.3.

6. If the supplier of water determines or has been informed by the State that the level of any contaminant exceeds the maximum contaminant level for the substance, he shall confirm such determination or information by repeating the analysis within 24 hours following the initial analysis or information, and then at least at weekly intervals during the period of time the maximum contaminant level for that substance has been exceeded, or until a

monitoring schedule as a condition to variance, exemption or enforcement action shall become effective. The results of such repetitive testing shall be averaged and reported as prescribed in paragraph (7) of this section.

7. To judge the compliance of a public water system with the maximum contaminant levels listed, averages of data shall be used and shall be rounded to the same number of significant figures as the maximum contaminant level for the substance in question. Each average shall be calculated on a past 12-month moving average basis if less than twelve samples per year are analyzed, and on a past three month moving average basis if twelve or more samples per year are analyzed. In cases where the maximum contaminant levels have been exceeded in any one sample, the average concentration shall be calculated on a one-month moving average basis and reported pursuant to 8.4.0. If the mean of the samples comprising the one month moving average exceeds the maximum contaminant level, the supplier of water shall give public notice pursuant to 8.1.3.

8. Sampling and analyses made to determine compliance shall be made in accordance with "An Improved Method for Determining Organics in Water by Activated Carbon Absorption and Solvent Extraction", Parts 1 and 2, Buelow, et al., Journal of American Water Works Association, 65: 57, 197 (1973).

9. Analyses made to determine compliance shall be made in accordance with "Method for Organochlorine Pesticides in Industrial Effluents", MDQARL, Environmental Protection Agency, Cincinnati, Ohio, November 28, 1973.

10. Analyses made to determine compliance shall be conducted in accordance with "Methods for Chlorinated Phenoxy Acid Herbicides in Industrial Effluents", MDQARL, Cincinnati, Ohio, November 23, 1973.

9.4.5 Radioactivity

Regulations for radiological substances are not included in the IPS. The EPA intends to publish proposed radiological maximum contaminant levels and analytical and sampling requirements in the near future. In the meantime, the frequency and location of sampling should be determined by the State after: (1) evaluating sources of radioactive material, (2) determining the likelihood of significant amounts being present. Under normal circumstances, monthly samples should be taken and composited quarterly for radioanalysis. Where other available evidence indicates that radioactive material is consistently absent, or is consistently below the approval limits for alpha or beta activity or for specific radionuclides, the frequency of sampling may be reduced subject to approval of the State. If the introduction of man-made or naturally occurring radioactive materials is suspected, samples should be collected more frequently to determine whether the approval limits have been exceeded and to record variations and changes.

9.4.6 Quality Control

The water utility should provide quality control for any treatment processes that are necessary for the production of water to conform to these Standards. Such quality control should be conducted continuously or frequently enough to ensure the maintenance of effective treatment. An example is control of the coagulation process.

9.5.0 Quality Evaluation

Water quality should be evaluated by comparison to the Federal Drinking Water Standards, and State and local requirements.

9.6.0 Public Information(VIII-5)

The interest and participation of an informed public is essential to achieving protection of water supplies. This suggests that in emergency situations there should be public notification (see IPS and Sections 8.1.3 and 8.4.0), and that information should be readily available to the customer with respect to:

1. Where the drinking water comes from;

2. How its quality is being protected at the source, in raw water storage and in transmission to the water processing plant;

3. What purification processes are employed;

4. What safeguards are used to prevent process or distribution system malfunctions;

5. What the substances are added for purposes other than water purification;

6. What the drinking water contains as it enters the water distribution system as revealed by analyses made to monitor compliance with water quality standards, including such information as sodium content, total dissolved solids and results of other tests that are made but for which no numerical standards have been set;

7. The qualification of principal water works employees including those of the person in direct responsible charge of the day-to-day operation of the water collection and processing works;

8. The agreement between the water utility and the various regulatory agencies as required by various provisions in the Federal Drinking Water Standards;

9. The status of compliance with Federal Drinking Water Standards including a record of measurements made during the current reporting period and how those measurements compare with the Standards;

10. Who is responsible for protecting and delivering water from the processing plant to the customer's connection;

11. Who to call in case of an emergency, to report some unusual condition, or to obtain information; and

12. Any other information which the customer would find helpful in considering health and welfare as they relate to his drinking water supply, such as a position on the use of home treatment units including their advantages and disadvantages.

The foregoing information should be assembled in format to facilitate easy reference and made available for public inspection during normal working hours at offices of the water utility. Some information can be summarized and forwarded with utility bill.

9.7.0 Operational Control Testing (IX-5)(IX-6)(II-43)(VIII-78)

9.7.1 General

Certain tests and analyses are necessary to properly control plant operation and the treatment processes. Such tests should present evidence that: (1) the water has been properly prepared for each major step in the treatment process; (2) that each unit process such as mixing, coagulation, sedimentation, filtration, activated carbon adsorption, softening, iron and manganese removal, disinfection, and taste and odor control has proceeded according to plan; and (3) the finished water is clean, has no objectionable taste or odor, has no excessive concentration of organic and inorganic chemicals, and is safe for human consumption.

9.7.2 Minimum Operational Control Tests

The number, type and frequency of process control tests depend upon the raw water quality, the rapidity of change in raw water characteristics, and the number of processes used in treatment. The location of sampling points should be such as to optimize process control as approved by the State.

9.7.2.1 Disinfection Only

Water works providing disinfection only or disinfection and re-disinfection should provide equipment for the measurement of residual disinfectant, pH, turbidity, and temperature.

9.7.2.2 Ion Exchange

Plants providing for removal of iron, manganese, or hardness by ion exchange should provide equipment for: residual disinfectant, iron, temperature, manganese, and hardness.

9.7.2.3 Fluoridation

Water works which fluoridate their water should provide equipment for determination of fluoride ion concentration and water temperature.

9.7.2.4 Softening

Chemical precipitation plants for water softening should provide an electric pH meter; equipment for determining alkalinity, hardness, temperature, and residual disinfectant; and a continuously recording turbidimeter on each filter effluent line.

It is also highly desirable to furnish equipment for coagulation control. Pilot filters are preferred, but jar test apparatus, zeta potential meters, streaming current detectors, and colloid titration apparatus may be useful in some situations.

9.7.2.5 Iron and Manganese Removal by Chemical Precipitation

In addition to the recommendations of Section 9.7.2.4, such plants should provide means to measure iron and manganese content.

9.7.2.6 Turbidity Removal

Plants utilizing turbidity removal should provide equipment for analysis of alkalinity, hardness, residual disinfectant, and water temperature. Continuous recording turbidimeters are recommended for: (1) raw water; (2) each filter effluent line; and (3) plant effluent. An electric pH meter and a backup pH color comparator should be furnished. For control of the coagulation process a continuous pilot filter with recording effluent turbidimeter, or an approved alternate could be used. Alternates to be considered are jar testing apparatus, zeta potential meter, streaming current detector, colloid titration apparatus, floc detectors, and submerged lights.

9.7.3 Chlorination Control

Effective chlorination control necessitates adjustments in chlorine feed not only to allow for variations in water flow, but also to compensate for any variations in water quality. For a particular water, the chlorine demand will vary with the amount of chlorine applied, the time of contact, and the temperature. Chlorine demand is the difference between the amount of chlorine applied to the water and the amount of free, combined, or total available chlorine remaining at the end of a specified contact period. Standard Methods defines two methods for determining chlorine demand. The kind and amount of chlorine residual required for a particular application relate to the objectives of treatment and vary from time to time and place to place. The control of chlorination processes is based on the attainment of a definite residual, which, after the contact afforded, has been established by experimentation and experience to accomplish disinfection. Quality control by bacteriological testing, coupled with statistical interpretation of results, is largely a matter of historical confirmation of treatment efficacy and provision of records to satisfy regulatory requirements.

9.7.4 Mixing Control

In plants which provide means for modifying the degree or duration of agitation, such factors may be varied to secure the best coagulation-filtration results as indicated by the coagulation control devices utilized in the plant.

9.7.5 Sedimentation Control

The objectives of coagulation, flocculation, and sedimentation may vary depending upon the plant design. In plants built prior to 1960 the objective was to remove as much settleable and colloidal material from the water as possible in the sedimentation basins prior to filtration. This mode of operation requires adjustment of chemical dosages to produce the best-selling floc. Often this chemical dosage is also consistent with maximum filterability. In some cases it is not, and it is desirable or necessary to optimize filterability by addition of a polymer or other filter aid to the basin effluent-filter influent water.

The practice in many new plants using coarse-to-fine filtration is to remove most particulates in the filter and to adjust initial chemical dosages for maximum filterability rather than maximum settleability.

Other than adjustment of chemical dosages, the plant operator has little control over the sedimentation process, except to make modifications in the basins themselves, such as the addition of settling tubes to permit higher throughput rates, or to add baffles to poorly designed inlet and outlet structures. The addition of settling tubes or baffles should be considered when excessive floc carryover is a problem.

9.7.6 Coagulation-Filtration Control(III-14)

The process of coagulation and filtration are inseparable in modern water treatment plant practice and control testing for the two processes must be discussed jointly.

9.7.6.1 Available Techniques

Achieving proper coagulation has been a problem faced by water treatment operators for many years and a wide variety of techniques have been developed for controlling the coagulation process. Most of these involve laboratory tests, the results of which then must be manually transferred to the full-scale plant operation by the plant operator. For example, the most widely used technique has been the conventional jar test. A sample of raw water is collected and transported to the laboratory where it is split into several samples in beakers. Varying coagulant doses are added to each sample and, after an appropriate period of mixing by a multiple paddle mixing device, stirring is stopped and the floc is allowed to settle. The clarity of the supernatant is then used to determine the optimum coagulation dose. In many cases, the operator's visual inspection of the supernatant is all that is used to select the best dose. Measurement of filtered supernatant turbidity in a batch, laboratory turbidimeter provides a more objective means of selecting the best dose of those tested. Whether or not the coagulant dose which provides the optimum result in a beaker will also provide optimum results on a plant scale depends on the unlikely fact that the same efficiency of mixing is achieved in both cases. Also, the fact that the procedure is a batch procedure results in an inherant time lag in responding to changes in raw water conditions. This lag may be only an hour if the operator is on duty and alert to raw water conditions but it may be several hours if he is off duty or involved in another task, such as equipment maintenance. This method may give satisfactory - even if not optimum - results when applied to a raw water of relatively uniform quality and which contains only a moderate amount of organic turbidity. For low turbidity waters and waters containing large amounts of organic material, no sharp distinction between coagulant doses near optimum may exist with the result that it is difficult to determine from the appearance of the sample whether adequate plant-scale results will be obtained. Although adequate control can be achieved under certain conditions by visual monitoring of jar tests, at other times it becomes a guessing game with each observer seeing characteristics which may or may not affect plant performance.

Coagulation control techniques fall into three general categories: (a) conventional and modified jar tests where visual observations of supernatant, floc formation time, floc density, etc., are used, (b) techniques based on particle charge, and (c) techniques based upon filtering the coagulated water and measuring the filtrate turbidity.

9.7.6.2 Jar Tests

A standard jar test procedure is contained within AWWA manual M-12 titled Simplified Procedures for Water Examination. A standard testing plan is required to provide a basis for the comparison of polymers as primary coagulants and for coagulation aids in a centrally directed program. The frequency of testing should be sufficient to optimize settling of filtration and to minimize chemical dosages.

Manual M-12 states "the jar tests are designed to show the nature and extent of the chemical treatment which will prove effective in the full scale plant. Many of the chemicals added to a water supply can be evaluated on a laboratory scale by means of jar tests. Among the most important of these chemicals are coagulants, coagulant aids, alkaline compounds, softening chemicals, and activated carbon for taste and odor removal. The test also permits the appraisal of the relative merits of the aluminum and iron coagulants, or in conjunction with such coagulant aids as activated silica, polyelectrolytes, clays, stone dust, acitvated carbon, settled sludge, lime, and soda ash".

The manual also notes several considerations that may affect the outcome of jar testing. It states "even the smallest detail may have an important influence on the result of a jar test. Therefore, all samples in a series of tests should be handled as nearly alike as possible. The purpose of the test will determine such experimental conditions such as flocculation and settling intervals. Since temperature plays an important role in coagulation, the raw water samples should be collected and measured only after all other preparations have been made, in order to reduce the effect that room temperature might have on the sample".

Equipment which may be utilized to evaluate polymers as coagulant aids is listed under a subsequent item of this Section.

The importance of simulating plant conditions as closely as possible cannot be overemphasized. The manual states "dosing solutions or suspensions should be prepared from the stock materials actually used in plant treatment. Distilled water used for the preparation of lime suspensions should be boiled for 15 minutes to expel the carbon dioxide and then cooled to room temperature before the lime is added". Details are presented in AWWA Manual M-12 on the preparation of coagulant dosing solutions and suspensions.

In testing polymeric coagulants or coagulant aids supplied by cooperating polymer manufacturers, solutions of these products should be prepared in accordance with manufacturer specifications.

9.7.6.3 Techniques Based on Particle Charge

(1) Zeta Potential

The first technique of this type to receive attention as a possible means of coagulation control was the zeta potential technique.

Zeta potential is a measure, in millivolts, of the electrical potential existing between the outer and fixed layer of counterions surrounding colloids and the bulk of the liquid in which the colloid is suspended. Because like charges repel, colloids in water - which are almost always negatively charged - resist coagulation. When this negative zeta potential is reduced, the repulsive forces are likewise reduced, and if agitated gently, the colloids will flocculate. In the treatment process, the reduction of zeta potential is accomplished by the addition of a positively charged ion or complex from such coagulants as aluminum sulfate, the iron salts, and cationic polyelectrolytes. The zeta potential is determined by observing microscopically visible particles as they move in an electric field.

Although zeta potential measurements are useful as a research tool, it is generally agreed that this method is not easily adapted to the typical treatment plant because of the considerable degree of skill and patience required to make the measurements and the amount of interpretation required to make the data useful. In plants which have purchased zeta meter equipment for routine operation, generally it will be found stored and inoperative. Popularity is declining recently for zeta potential as a control technique. It is also subject to the same shortcomings of any other batch test in that sudden changes in raw water conditions may not be detected until a poor quality finished water occurs in the full-scale plant.

(2) Streaming Current Detector

A streaming current detector may be used to provide a continuous measure of the relative charges. This technique involves placing a sample in a special cylinder containing electronic sensing electrodes at the top and bottom. A loose-fitting piston is then partly submerged into the sample, and is reciprocated along its axis to produce an alternating current between the electrodes when the cylinder contains moving charges. A synchronous motor drives the piston and a synchronous rectifier switch by means of which the alternating current generated by the alternating fluid motion is made to register on a dc meter. Am amplifier with adjustable negative feedback is used to provide an output proportional to the current collected by the electrodes. Readout may be by a microammeter, with calibration in arbitrary units. The alternating current is analyzed and related to zeta potential, which can be used to control coagulant dosage. A flow-through cylinder and recording ammeter may be built into the system to permit continuous monitoring.

The continuous nature of the streaming current detector may make it attractive in some instances where cationic coagulants are used in a water which shows little variation from season to season.

(3) Colloid Titration

A simple titration technique using an indicator that changes colors when a solution is titrated to electric neutrality has been developed. An excess amount of positively charged polymer is added to the naturally negatively-charged water.

It is then back-titrated with a standard negatively-charged polymer. An empirical correlation is used to relate the volume of titrant to the proper coagulant dosage, in a manner analogous to zeta potential measurement.

Like the streaming current detector, colloid titration has the advantage of using a larger, more representative sample than is used in zeta potential measurements. Since its conclusions are based on the electrokinetic properties of a suspension, its results are subject to the same limitations given for the streaming current detector and the zeta potential devices.

9.7.6.4 Continuous Filtration Techniques(III-14)

(1) Pilot Filters

Because the goal of the water treatment plant should be to produce the minimum possible filter effluent turbidity at, preferably, the minimum chemical costs, it is logical that perhaps the best measure of the efficiency of the coagulation-filtration steps would be the direct, continuous measurement of the turbidity of coagulated water which has passed directly through a pilot granular filter. The application of continuous turbidity monitoring equipment to the effluent of the plant scale filters should be a must for monitoring plant performance but has limited value as a control technique due to the substantial lag time between the point of chemical coagulant addition and the point of filtrate turbidity monitoring. For example, improper coagulation of the incoming raw water will result in a clarifier (with typically 1 ½ - 3 hr. of detention time) being filled with improperly coagulated water before the results will become fully apparent at the discharge of the plant filters.

The pilot filter technique is applied by sampling the plant treated, coagulated water from the discharge of the plant rapid mix basin. This sample stream is then passed through a small, usually 12 cm (4 ½ inch) diameter pilot filter to determine if the coagulant dose is proper by continuously monitoring the pilot filter effluent turbidity. This technique provides a continuous, direct measurement of the turbidity which can be achieved by filtration of the water as it has been coagulated in the actual plant. Thus, no extrapolation from small-scale laboratory coagulation experiments is required. The only purpose is to determine the proper coagulant dose. It is not to predict the length of filter run, nor to determine the optimum filter aid dose, nor to predict the rate of headloss buildup. Pilot filter columns have been used for these other purposes, but the technique of interest here is that used for monitoring of the coagulation process.

The pilot filter technique has the advantage of offering a continuous monitoring of the plant-scale coagulation process with a minimum lag time. Filtering the water through the pilot filter yields an immediate answer as to the adequacy of the coagulant dosage. In a typical situation, correctness of coagulant dose is determined within 10 to 15 min. after the raw water enters the plant. Experience at many locations shows that the pilot filter effluent turbidity is a very accurate prediction of the turbidity that will be produced by the plant scale filter when the corresponding water reaches the plant scale filter.

The mixed-media filter bed design described previously is often used in the pilot filter. The mixed-media design has the ability to accept the high solids load associated with most unsettled, coagulated waters without excessive headloss buildup. The turbidity of the pilot filter is monitored continuously and recorded. High turbidity in the filter effluent could result from either an improper coagulant dose or a breakthrough of floc from a properly coagulated water. To insure that breakthrough does not occur, supplemental doses of polymers are injected into the pilot filter influent line. These large polymer doses may shorten the pilot filter run times but, to insure that breakthrough does not occur, it is desirable to backwash the filter every 1-3 hours in any case, to insure that it is always relatively clean. To insure that a continuous monitoring of the coagulation process is provided, 2 pilot filters are used in parallel. The system is equipped so that the filters backwash automatically on a high headloss signal. When one pilot filter enters the backwash cycle (which requires only about 10 min.), the other pilot filter is automatically placed in service. Where very high raw water turbidities can be expected, a miniature flocculator-tube settler device can be installed ahead of the pilot filters to insure reasonable filter run times even during periods of high turbidity.

Typically, the pilot filters are contained in a console unit or in the plant control panel which may also house turbidimeters for monitoring the plant-scale filter effluent turbidity.

Currently, two manufacturers offer commercial pilot filter systems, both based on the same principal but differing somewhat in mechanical aspects. One unit contains two 12 cm (4 ½ inch) diameter cylindrical, pressure pilot filters. A large number (about 200) of these units are in service.

Another pilot filter unit uses a tapered column to reduce the problems of media bridging the pilot columns during backwash. Also, this system uses an open top gravity filter to reduce the number of valves required. As the exact volume of flow through the filter is not critical, an excess of flow to the gravity filter is maintained at all times with the excess overflowing to a trough and then to waste.

The pilot filter system can be used to accurately indicate coagulation conditions with a minimum lag time so that the operator can make the necessary adjustments in the plant chemical feed. Alternately, the coagulant feed can be controlled automatically by using the pilot filter effluent turbidity signal to automatically adjust the plant coagulant dosage to maintain the effluent turbidity from the pilot filter at a desired set point value regardless of variations in raw water quality and other related factors.

(2) Filter Aid Control By Interface Monitoring

This technique has been developed in conjunction with dual-media filters. A sample of water is removed from the filter at a point near the interface between the coarse anthracite coal and the fine sand. The turbidity of this sample is continuously monitored and recorded, as is the filter effluent turbidity. The sample at the interface is obtained with a device which is a specially constructed well screen with slits small enough so that the coal and sand cannot pass through. The interface screen is placed

5 cm (2 in.) above the fine sand prior to anthracite placement. The turbidimeter is placed as close as possible to the filter. Samples flow by gravity to the turbidimeters. This prevents air bubbles which frequently occur when turbidimeter samples are pumped and also provides for the fastest possible response time. The interface turbidity sample is designed as a tool to aid the treatment plant operator in obtaining optimum performance from a dual media filter. The turbidity value obtained at the interface indicates where floc removal is occurring within the filter bed. For instance, a high interface turbidity and a low filter effluent turbidity indicates the proper coagulant dosage is being used but that significant amounts of floc are penetrating through the anthracite layer and must be removed by the fine sand. If the sand is forced to carry too much of the load, the headloss buildup becomes excessive, or breakthrough of turbidity could occur into the effluent. When floc removal does not occur in the anthracite layer when the proper coagulant dose is applied, the floc strength is inadequate and should be increased by the feed of polymers. This method works with any material which can be successfully used as a filter aid or conditioner. The filter aid must be started at a known underdose and incrementally increased until the desired floc removal is obtained in the coal layer. If an overdose is applied, it is usually impossible to use the interface concept until the filter has been washed. It may also be desirable to adjust the filter aid dosage during the filter run, beginning with no aid or a small amount, and increasing the dosage as the run progresses.

9.7.7 Turbidity Monitoring(III-14)

With the currently available, low cost turbidimeters, which are accurate and require little maintenance, every municipal water plant in this country, regardless of size, should provide a continuous record of the quality of its final product. Turbidity is an important parameter in that it reflects the efficiency of the coagulation process and the overall treatment provided, is related to probability of escape of pathogenic organisms from the treatment plant, and is a sensitive indicator of the aesthetic acceptability of the product to the consumer. An appalling number of plants provide no continuous monitoring of plant effluent turbidity. There are very few production-oriented industries which do not maintain better quality control procedures than the water treatment industry, the performance of which is directly related to the public health of the nation.

For the measurement of very small amounts of turbidity, the principle of light scattering (nephelometry) is used. In this process, light is reflected at right angles to the light beam by the particles of turbidity in the liquid, as the beam of light passes through the liquid. The amount of reflected (scattered) light depends directly upon the amount of turbidity present in the liquid. This is similar to the common phenomenon of sunlight streaming through a window being reflected by otherwise invisible dust particles in the air.

If the liquid is entirely free of particles of turbidity, no scattered light will reach the photocells, and the indicating meter will read zero; thus, increasing turbidity gives an increase in meter reading.

The advantageous features of this system of turbidity measurement are:

1. A very strong light source can be used which permits a high degree of sensitivity; thus very small amounts of turbidity can be measured accurately.

2. The meter or output from the instrument is zero when the turbidity is zero.

Units of this type are available with ranges of 0-0.2, 0-1, 0-3, and 0-30 turbidity units. A water sample of approximately 1.9 Lpm (0.5 gpm) at a head of 15 cm (6 inches) of water is required.

9.8.0 Laboratory Control (IX-56)(IX-5)(VIII-8)(VIII-78)(VIII-67)

9.8.1 General

Each public water supply should have adequate laboratory equipment and capability to perform the operational tests (except bacteriological, trace organics, and heavy metals) appropriate to the parameters to be tested and to the type of treatment employed (see Section 9.7.2). Such equipment should be in good operating condition, and the operator on duty should be familiar with procedures for performing the tests. If the utility performs bacteriological examinations, the laboratory equipment and personnel should be approved by the State. However, nothing in these Standards shall be construed to prevent a utility from running bacteriological tests in an uncertified laboratory, but such results are not to be included in the sample quota for the supply.

There are four basic reasons for laboratory testing at water treatment plants: (1) process control, (2) cost control, (3) historical data, and (4) requirements of regulatory agencies for safety and health protection. Process control testing includes those tests necessary to insure that each unit process is operating properly. Minimum on-site testing includes all process control tests except those for heavy metals and trace organics which may be performed off-site in a private, local, regional, state, or federal laboratory. Cost control testing is meant to minimize operating expenses at the treatment plant, and the location and manner of testing is optional with the water utility. Historical testing includes raw and treated water analyses and treatment plant performance under various operating conditions and at different hydraulic loadings. This type of historical data provides a basis for evaluation of plant design parameters and their refinements and improvement in future expansion of plant capacity and treatment capability. Most of the testing for record purposes must, out of necessity, be performed at the plant site. The testing required by regulatory agencies is that which is necessary to demonstrate compliance with health and safety standards, and much of this work can be done either in the plant laboratory or by an outside laboratory.

9.8.2 Physical and Chemical Examination of Raw and Treated Waters

The collection of samples; the laboratory apparatus, reagents, and techniques; and the expression of results of chemical analysis all should conform to the requirements set forth in the current edition of Standard Methods for the Examination of Water and Wastewater.

9.8.3 Checking and Reporting Results

The correctness of analyses should be checked by making an anion-cation balance and by other procedures described in Standard Methods for Examination of Water and Wastewater. In reporting results, round off figures to the nearest significant digit, dropping the digits which are not significant. Report only such figures as are justified by the accuracy of the work.

9.8.4 Laboratory Facilities

Adequate monitoring requires a well-equipped laboratory. The size of the laboratory depends upon the nature of the processes to be controlled and, to a lesser extent, upon the size of the water plant. All space should be clean, well-lighted, comfortable (air-conditioned), and used for laboratory purposes only. For small plants, the various laboratories such as sample preparation, chemistry, bacteriology, and microscopy may be consolidated into one room, with the various functions being assigned to different sections of the room. In larger plants, a better arrangement can be provided by housing each type of laboratory in an individual room. Separate laboratory rooms may be provided for plant operators and laboratory personnel, where the respective work areas are widely separated.

The laboratory equipment should be adequate to permit proper analytical control of the treatment process. In the paragraphs which follow, itemized lists of equipment are given for various types of treatment plants. These suggestions provide minimum facilities in each case, and many water utilities will want to install larger and more completely equipped laboratories.

9.8.4.1 Disinfection Only

As indicated in Section 9.7.2.1, plants providing disinfection only, or only disinfection and re-disinfection shall provide space, facilities, and equipment for the measurement of residual disinfectant, pH, and temperature.

(1) It is recommended that the minimum laboratory floor space, work bench area, and cabinet volume be provided as shown in Table 9.8-1.

TABLE 9.8-1(IX-56)

Recommended Minimum Water Plant Laboratory Floor Space, Work Bench Area, and Cabinet Volume According to Plant Size.

Plant Capacity		Min. Lab. Floor Space		Min. Work Bench Area		Minimum Cabinet Volume	
mLpd	mgd	SqM	SqFt	SqM	SqFt	CuM	CuFt
3.8 or less	1 or less	17	180	1.1	12	5.7	200
3.8 to 19	1 to 5	28	300	1.7	18	8.5	300
19 to 38	5 to 10	56	600	2.2	24	14.2	500
38 to 95	10 to 25	74	800	2.9	30	18.4	650
95 or more	25 or more	112	1,200	3.3	36	22.6	800

(2) Provide laboratory sink with hot, cold, and distilled water.

(3) Furnish the following laboratory apparatus:

Laboratory Apparatus - Disinfection Only

Quantity	Description
1	Color comparator for determining pH in the range of 6.0 to 8.4 and for measurement of the relative amounts of free available chlorine, combined available chlorine, and color due to interfering substances by the DPD or OTA (orthotolidine-arsenite) method over a range of 0.1 to 2.0 mg/l. The unit shall be complete with permanent color standard discs for pH and chlorine measurements and with supplies of orthotolidine reagent, arsenite reagent, bromthymol blue, and phenol red.
1	Amperometric titration outfit for determination of chlorine residuals including end point detection apparatus, agitator, buret, phenylassenoixide solution, potassium iodide solution, phosphate buffer solution, and acetate buffer solution.
(option)	If a disinfectant other than chlorine is used, suitable reagents, equipment, and apparatus shall be provided for determining concentrations of the disinfectant in water.
1	Thermometer, mercury - filled, with range of 0 to 100° Centigrade.
2	Glass bottles, 5 gallon, for distilled water.
6	Bottles, wide-mouth, glass-stoppered, 32 ounce.
18	Bottles, wide-mouth, glass-stoppered, 125 ml.
3	Bottles, dropping, 60 ml.
2	Bottles, wash, 1,000 ml.
2	Cylinders, double graduated, 100 ml.
6	Flasks, Erlenmeyer, Pyrex, 250 ml.
4	Flasks, Erlenmeyer, Pyrex, 500 ml.
4	Beakers, Pyrex, 250 ml.
2	Beaker covers, 3 ½ inches.

Quantity	Description
2	Funnels, long stem, 100 mm diameter.
2	Burettes, 50 ml, graduated in 0.1 ml.
1	Pipettes, volumetric, Exax blueline, 1 ml.
1	Pipettes, volumetric, Exax blueline, 25 ml.
1	Pipettes, volumetric, Exax blueline, 50 ml.
2	Evaporating dishes, porcelain, 75 mm.
1	Hotplate, electric or gas, 2-burner.
1	Harvard trip scale balance.
1 set	Balance weights, 1 to 500 grams.
1	Gas burner, Bunsen.
1	Stone jar for waste, 2 gallon.
1	Clamp, test tube.
1	File, triangular, 6 inch.
1	Funnel support, hardwood.
1	Ring stand, iron, 3-ring (3", 4", 5").
1	Wire gauze, 4 inch.
1	Triangle, 2 ½ inch.
1	Tongs, 9 inch.
2	Brushes, flask.
2	Brushes, tube.
12 feet	Rubber tubing, ¼ inch bore.
6 feet	Rubber tubing, 1/8 inch bore.
1 bag	Corks, assorted sizes 3 to 16.
1	Cork borer set, size 5 to 11 mm.
1 lb.	Rubber stoppers, assorted.

Quantity	Description
2 boxes	Filter paper, 9 cm.
1 box	Filter paper, 12.5 cm.
2	Pencils, glass marking.
1 book	Standard Methods for the Examination of Water & Wastewater.

9.8.4.2 Ion Exchange

Plants providing for removal of iron, manganese, or hardness by ion exchange shall provide all of the laboratory space, facilities, and apparatus specified in Table 9.8-1 and under Section 9.8.4.1, and, in addition, shall provide means and apparatus for measuring materials to be removed (iron, manganese, and/or hardness).

Quantity	Description
	Iron Removal
1	Set of apparatus and reagents for determining iron by the phenanthroline and tripyridil methods.
2	Platinum crucibles.
1	Spectrophotometer, for use at 510 and 555 mu with light path of 1 to 10 cm, or alternately, filter photometer with green filter having maximum transmittance at 510 and 555 mm, and a 1 to 10 cm light path.
24	Nessler tubes, matched, 100 ml tall-form.
	Hydrochloric acid, concentrated.
	Sodium acetate solution.
	Hydroxylamine reagent.
	1, 10-Phenanthroline solution.
	Standard iron stock solution.
	Tripyridil solution.
	Ethylenediamine.

Quality	Description
	Manganese Removal
1	Set of apparatus and reagents for determining manganese by the periodate and persulfate methods.
1	Spectrophotometer, for use at 525 mu, with a light path of 1 to 15 cm, or, alternately, a filter photometer providing light paths of 1 to 15 cm and equipped with a green filter having maximum transmittance of 525 mu.
24	Nessler tubes, matched, 100 ml, tall-form.
	Manganous sulfate, standard solution.
	Nitric acid, concentrated.
	Phosphoric acid, 85 percent.
	Sulfuric acid, concentrated.
	Solid potassium meta-periodate.
	Silver nitrate.
	Hydrogen peroxide solution, 28 percent.
	Mercuric sulfate.
	Ammonium persulfate, solid.
	Hardness Removal
1	Set of apparatus and reagents for determining hardness by the EDTA titration method, including EDTA titrant, indicator, and inhibitor solutions.

9.8.4.3 Fluoridation

Plants which fluoridate their water should in addition to other requirements for laboratory control as provided by Table 9.8-1 and by applicable Sections 9.8.4.1, 9.8.4.2, 9.8.4.4, 9.8.4.5., 9.8.4.6, provide equipment for determination of fluoride ion concentration by the Alizarin Visual, Photometric, or Electrode Methods, See Chapter VI, page 63, EPA "Fluoridation Engineering Manual, 1972".

9.8.4.4 Softening

Chemical precipitation plants for water softening should provide all of the space facilities and equipment specified in Table 9.8-1 and under Section 9.8.4.1. In addition, they should provide (1) equipment for determining alkalinity and hardness; (2) an electric pH meter; (3) continuously recording turbidimeters on each filter effluent line; and (4) jar test apparatus.

Additional Laboratory Apparatus for Plants Softening by Chemical Precipitation

Quantity	Description
	Fiftieth normal sulfuric acid.
	Phenolphthalein indicator.
	Methyl orange indicator.
1	Pipette, 100 ml.
1	Burette, 50 ml.
1	Porcelain casserole.
1	Erlenmeyer flask, 200 ml.
1	Set of apparatus and reagents for determining hardness by the EDTA titration method, including EDTA titrant, indicator, and inhibitor solutions.
1	Electric pH meter.
1	Continuously recording turbidimeter on each filter effluent line.
1	Jar test apparatus for determining coagulant dosages consisting of a mechanical device for simultaneously stirring water samples in six 1000 ml beakers at speeds variable from 1 to 100 rpm. (If raw water quality is variable, consider use of more sophisticated means for coagulation-filtration control - see Section 9.7.2.4).
1	Balance, analytical, single pan, substitution weighing, digital indicating with optical tare; plus double beam balance, dial weighing, magnetic damper.

Quantity	Description
1	Blender, reducing and emulsifying, 2-speed, 1 liter capacity.
1	Bookcase, 4 shelf, 1 meter (30 inch) length, 0.3 meters (1 foot) deep.
1	Centrifuge, clinical, 6 place, 15 ml, plus polycarbonate tubes, graduated 15 ml.
1	File cabinet, 4 drawer.
1	Fume hood, with gas and cold water fixtures, cup sink, and electrical receptacle.
1	Lab stool.
1	Magnetic stirrer, variable speed.
1	Microscope, 10X ocular, 4X, 10X, and 43X objectives.
1	Muffle furnace, 1900°F maximum temperature, approximately 4 x 5 x 6 inches.
1	Desk, office.
1	Oven, gravity convection, single-wall, electric, 200°C thermostatic control, approximately 9 x 12 x 12 inches.
1	Pump, vacuum-pressure, rotary, motor-driven, 1.3 cfm of air, 15 psig maximum continuous pressure, 15 inches of mercury maximum continuous vacuum.
1	Refrigerator.

9.8.4.5 Iron and Manganese Removal by Chemical Precipitation

Such plants should provide all laboratory control facilities specified in Table 9.8-1 and under Section 9.8.4.4, and, in addition, should provide the apparatus for making analyses for iron and manganese as specified under Section 9.8.4.2.

9.8.4.6 Turbidity Removal

Plants removing turbidity should provide all of the laboratory facilities and apparatus specified in Table 9.8-1 and under Section 9.8.4.4. The plant shall also include continuously recording turbidimeters on the plant raw water and finished water line.

For control of the coagulation-filtration process it is recommended that a continuous pilot filter with recording effluent turbidimeter, or an approved alternate, be provided (see Section 9.7.2.6).

For turbidity removal plants, particularly plants serving more than 30,000 people, serious consideration should be given to provision of an in-plant, state-approved bacteriological laboratory for conducting coliform tests by the multiple-tube and membrane filter methods.

9.8.4.7 Laboratory Layout

The efficiency of laboratory operations can be greatly improved by good planning in the layout and arrangement of laboratory facilities. Proper arrangement of work areas, the number and location of sinks and electrical outlets, the arrangement of laboratory equipment, materials of construction, and lighting all can contribute to convenience and efficiency of laboratory work.

Windows in the north side of the laboratory are preferred because they produce more uniform natural lighting. Adequate artificial lighting is needed and color corrected fluorescent lighting is suggested.

Wall and floor finishes should be light in color and nonglare. Flat finish wall paint is suggested. Floor finishes should be single color, easy to clean, and comfortable.

Aisle widths between work benches should be at least 1.2 meters (4 feet). Provide adequate space for cleaning around floor-standing equipment, work benches, desks, and file cabinets.

Storage space for reagent stock should be under (not over) work benches.

One wash sink and one cup sink should be provided for each 9 meters (30 feet) of length of work bench.

Duplex electrical receptacles should be provided at 1 meter (3 foot) intervals and gas outlets at 5 meter (15 foot) intervals along benches used for laboratory tests.

Bench tops should be suitable for heavy duty work and resistant to chemical attack. Resin impregnated natural stone provides such a surface.

Bench surfaces should be 0.9 meters (36 inches) high for standing work and 0.76 meters (30 inches) high for sitting work. Bench surfaces should be at least 0.76 meters (30 inches) wide.

Equipment and apparatus should be placed in locations which take into account their order and frequency of use. Fume hoods should be located near the main work area. For safety, the first aid kit, fire extinguisher, eye wash, and emergency shower should be located near the main working area of the laboratory.

The analytical balance should be placed on a solid table not subject to vibrations which has a top surface not less than 0.6 x 0.76 meters (24 x 30 inches).

A separate table for the microscope is desirable. It should be 0.6 x 0.76 meters by 0.68 meters high (24 x 30 x 27 inches high).

9.9.0 Laboratory Personnel and Staffing (IX-5)

Laboratory personnel should be educationally qualified and well trained in water treatment plant control. They should be certified by examination as to their qualifications by the appropriate state department of health. The person in charge of the laboratory preferably should be a sanitary engineer, chemist, or bacteriologist, with a background of experience in laboratory control of water treatment processes. In small plants, the chief operator should be certified as to his laboratory qualifications in the absence of an engineer, chemist, or bacteriologist. All plant operators should have training in laboratory techniques as provided by state and federal waterworks short courses.

A rough guide to overall laboratory manpower requirements is given in Table 9.9-1:

Table 9.9-1

Estimated Water Laboratory Manpower Requirements for

Treatment Plants of Various Capacities

Treatment Plant Size		Estimated Laboratory Hours Per Year	Approximate Full Time Positions
mLpd	mgd		
3.8	1	400 to 500	0.2 to 0.25
19	5	800 to 2,000	0.4 to 1.0

Treatment Plant Size		Estimated Laboratory Hours Per Year	Approximate Full Time Positions
mlpd	mgd		
38	10	1,000 to 2,600	0.5 to 1.3
57	15	1,300 to 4,000	0.65 to 2.0
76	20	1,500 to 4,400	0.75 to 2.2
95	25	1,700 to 4,800	0.85 to 2.4

RATIONALE FOR SURVEILLANCE STANDARDS

9.1.0 Surveillance

The key to safe water lies in the combination of quality of source, the nature of physical facilities, the operation and management of the facilities, and the capability of this combination to produce and deliver water of a given quality. The continuous surveillance of water quality is a most important means of assuring delivery of high quality water at all times.

Tests to control water treatment should be designed to show that the water has been properly prepared for each major step in the treatment process, that each unit process has proceeded according to plan, and that the finished product is clear, free from taste, odor, and undesirable chemicals, and is safe for human consumption. Since public safety is a primary objective of every potable water plant, adequate tests and records are essential to determine and demonstrate quality of the product.

Regular sanitary surveys by the water utility and state and federal regulatory agencies of the source of supply, treatment plant, storage reservoirs, and distribution system are recommended to assure that there are no new sources of pollution or new types of pollutants which might adversely affect raw water quality, that there are no uncorrected equipment failures, and that no changes have occurred which might allow contamination of treated water in storage reservoirs or mains.

9.2.0 Responsibility

The assignment of legal responsibility in the Standards is governed by legal considerations. The water utility (or combination of agencies comprising the water utility) is responsible for conditions in the water supply system over which it has legal control, that is, from the source of supply to the point of connection to the customer's service piping. From that point to the free-flowing tap the owner of the property exercises legal control over water quality preservation subject to regulations of the local authority having police power in such matters, usually a municipality or county agency.

9.3.0 Source and Facilities Surveillance

9.3.1 Reliability of System

The degree of reliability which is sought in public water supply systems is that which will permit the full compliance with water quality standards at all times at all points of withdrawals from the system. This must be done at times when everything is normal, and, insofar as possible, it must also be done under abnormal conditions taking into account power and equipment failures, human errors and omissions, natural disasters, and accidents.

9.3.2 Source

Prevention of water quality degradation at the source is a task which requires continuous attention and surveillance, particularly in those instances where minimal or no treatment is provided or where the treatment process installed will not remove an added contaminant.

9.3.2.1 Surveys

The creation of new sources of pollution or the introduction of new contaminants in existing waste streams entering a water supply source, may require adjustments in treatment or plant additions. The need is obvious for a regular systematic survey program to locate and identify health hazards of this kind and to make necessary changes and additions in the water system to accomodate new developments.

9.3.3 Treatment

Surveillance and laboratory control tests are essential to determine whether or not the existing treatment processes are needed or are adequate to produce the desired quality of water with a high degree of reliability.

Treatment additions, and, in some cases, deletions can be made based on the observed results of raw water tests and finished water quality.

9.3.4 Water Supply Systems

Regular systematic surveys of storage and distribution facilities are necessary to determine the adequacy of existing protection and to locate new hazards to water quality which may have been recently created or previously overlooked.

9.4.0 Sampling Frequency

The frequency of sampling specified in these Standards conforms to the Federal Drinking Water Standards, the IPS, and to local and State regulations. These Standards and regulations are based on statistically significant numbers in many cases, and upon past experience in the water works industry in controlling water quality.

9.5.0 Quality Evaluation

Whether a particular water conforms to minimum quality standards can be readily evaluated, provided sufficient water samples have been collected and properly analyzed, by comparing plant records to the Federal Drinking Water Standards and to local and State requirements.

Further evaluation can be made by comparison of plant results to the Water Quality Goals established by the AWWA.

9.6.0 Public Notification

This subsection lists some items of information which interest water consumers, and about which they should be notified by the water utility if public support is to be gained for protection and improvement of water systems.

9.7.0 Operational Control Testing

9.7.1 General

Day to day operation of water systems requires that a certain minimum number of water samples be collected and analyzed in order to properly operate the plant and to control product quality.

The frequency, type, and number of analyses required depend greatly upon raw water quality and the complexity of treatment provided.

9.7.2 Minimum Operational Control Tests

The minimum testing program specified for each type of treatment objective listed is based upon testing for anticipated changes in quality to be accomplished by the treatment provided and the minimum information needed to assure water safety. These programs have been developed from current practices and experience in the water works industry.

9.8.0 Laboratory Control

9.8.1 General

The primary purposes of plant laboratory control tests is to control water treatment, and special emphasis should be placed on tests that are of immediate value in the assessment of water quality and safety. Residual chlorine and turbidity tests are in this category. Consideration should be given to instrumentation of such early value tests to provide continuous recording at strategic points in the treatment process. Filter effluent and plant effluent turbidimeters, residual chlorine and pH recorders, and pilot filters for optimizing coagulant dosages are examples of equipment that have proved their value in plant operation.

The number of water samples examined each day will depend on the quality of the raw water, the rapidity with which raw water characteristics change, the number of processes used in treatment, and the number of processing units installed. In general, the number of water samples examined at each stage in the total treatment should be adequate to provide positive control and assure the delivery of quality water to the public. To check each step in treatment, samples should be collected hourly. For chemical and bacteriological testing, samples should be collected on each shift, or three times daily. Tests for turbidity, residual chlorine, color, and alkalinity are of primary importance and should be performed on each shift with corrections and adjustments in treatment being made by the operator as indicated in accordance with planned and approved procedures. Confirmation should follow by the chief operator or plant chemist. These primary control tests are simple and should be made frequently. They are the first signals of changes in raw water quality and plant performance and thus form the first line of treatment process control. Frequent control tests throughout the entire day are the means by which safety and uniform quality of product can be assured. Even greater assurance can be obtained by continuous, automatic monitoring where possible.

Examination of water samples taken regularly from established sampling stations on the distribution system for chlorine residual, turbidity, taste and odor, and bacteria is recommended to ascertain that the water is of high quality as it reaches the consumer. Water quality deterioration in the mains is possible and must be recognized and controlled. The frequency of sampling in the distribution system should be not less than the recommendations of the Federal Drinking Water Standards.

In addition to the primary control tests mentioned above, many laboratories also routinely test for hardness, taste, odor, calcium, and total and dissolved solids. Plants using lake, stream or impounded water may make algal examinations regularly. Plants utilizing coagulation-filtration should provide a program of testing designed to establish the efficiency of these processes. To establish the efficiency of filtration, equipment should be provided for measuring turbidity values as low as 0.1 JU. When softening is practiced, accurate determinations of calcium and magnesium are required. For iron and manganese removal or for taste and odor control, daily tests should be made. Since public safety is a primary objective of every water system, adequate tests and records of bacteriological quality are ever essential.

Personnel in the average water plant laboratory are not expected to make tests for all the trace elements and chemicals (such as arsenic, CCE, cyanide, and the like), however, such tests should be made by qualified laboratories at intervals required by the IPS.

9.8.2 Physical and Chemical Examination of Raw and Treated Waters

It is very important that the sample collection procedures, test methods, and the expression of test results all conform to the requirements of Standard Methods for the Examination of Water and Wastewater. If short cut methods of analysis are used, the test results should be checked frequently to assure that any errors introduced are not sufficient to affect conformance of the water produced to the Federal Drinking Water Standards.

9.8.3 Checking and Reporting Results

Good, accurate, complete records are usually a reflection of similar performance in plant operation.

Records are used for review purposes, for changes and improvements in operations, for cost control, for future planning, for evidence and for financial purposes. As the use of computers increases, it can be expected that records of water quality and plant performance will become even more useful as the various interrelationships are analyzed more fully.

To utilize the mass of data obtained from daily plant records, it should be summarized and placed on a monthly summary sheet as a permanent record.

9.8.4 Laboratory Facilities

The laboratory facilities described in these Standards, Section 9.8.4, are those recommended for minimum plant control testing. Additional facilities may be required for plants in which more testing is to be done for record purposes, and for research and development.

The facilities and equipment specified are based on information given in Standard Methods for the Examination of Water and Wastewater and experience in existing plants.

Laboratories must be tailored for each facility and each individual set of circumstances, because of the wide variety and numerous combinations of treatment processes and raw water conditions.

The suggested laboratory facilities are not strict regulations, but are guidelines to development of a water laboratory which will assure efficient operation of the treatment plant and water system.

9.9.0 Laboratory Personnel and Staffing

Adequate staffing depends upon a number of factors including: raw water quality and type of treatment; the extent of use of automatic samplers; the extent of use of automatic monitoring and recording of water characteristics; the degree of use of contracted laboratory work; the level of training of laboratory personnel; and the laboratory equipment used.

SECTION X PERSONNEL

SUMMARY OF PERSONNEL STANDARDS

10.1.0 Personnel - General(X-2,7,62)

A classification system for water facilities and personnel is given in, "ABC-A Classification System for Water and Wastewater Facilities and Personnel" by the Association of Boards of Certification for the EPA, June, 1974. This classification system takes into account size and complexity of different water systems.

The people who manage, operate, and maintain water systems are the ultimate key to the success or failure of the utility. The personalities, character, education, and experience of utility employees are the factors which determine the fate of water system performance. Good personnel can make even mediocre facilities give excellent results, and poor personnel can cause the best of facilities to malfunction.

New employees should be selected on the basis of aptitude, training, experience, and character.

Salary scales and benefits of the water utility should be high enough to attract good competent employees.

1. Each water utility should make a careful study of its wage, salary and benefit policies; that is, study all available material, and determine if it is paying salaries and providing benefits competitive with those paid in other utilities and in other industries that will attract and retain the necessary qualified personnel.

2. Recent salary surveys demonstrate the low and inadequate salaries being paid to the personnel of many water utilities. This is especially true in the small and in the governmental-owned water utilities.

3. Water utilities need to select employees with adequate educational backgrounds and qualifications and also encourage better utilization of training programs, short courses, seminars, etc. in order to justify higher salaries and better benefits.

4. All water utility managers should have at least a high school education.

5. Water utilities serving a population of 10,000 or more

should have a full-time, graduate (or equivalent), registered professional engineer in its employ.

6. Any utility serving a population of 25,000 or more should have a college graduate (or equivalent) as its manager.

7. Employee benefits are an integral part of wage and salary policies. They are a substantial part of payroll costs; $1.907 per hour worked, or 33.5 percent of gross payroll in the U.S. as indicated by a recent survey.

8. In general, the investor-owned segment of the industry is doing a better job of meeting competitive wage, salary and benefits policies than are governmental-owned utilities.

9. Many water utilities do not keep cost accounting records that permit an intelligent administration of employee benefit policies. Such records should provide management with the actual cost of each employee benefit, as well as the total cost. The records should show such costs in cents per hour actually worked and percentage of payroll and also total annual cost.

10. Employees generally have no concept of either the cost of employee benefits or how vital these benefits have become to their security and welfare.

11. Water utility managements, like managements in other industries, need to do a much more effective job in communicating employee benefit facts to their employees.

12. By and large, the water utility industry is not keeping up with other industry and other utilities in either wages, salaries, or employee benefits.

An organization manual and written copies of all personnel policies and practices should be furnished to each new employee. Equal employment opportunity should be addressed and practiced. The utility should inform each new employee of his conditions of employment, duties, responsibilities, authority, and benefits on the job. A job description should be developed for each job within the utility. Proper supervision should be provided for all employees. Employees should be treated fairly without prejudice or favoritism. Supervisors should be trained in management techniques. Employees should receive technical instruction and information on responsibilities which have been assigned or delegated to them. They should be praised for work well done, and immediately informed in a constructive way of shortcomings.

For each employee the utility should maintain adequate records for personnel evaluation. The utility should establish standards for worker performance based on job evaluation which has been thoroughly explained to the worker at the time of employment. Whenever possible, promotions should be made from within the organization.

Annual reviews should be made by supervisors of the performance of each employee, followed by a discussion with the employee. Comparisons of utility wage rates and benefits to those for comparable jobs in other parts of the community and region should be reviewed.

Each employee should be given a manual describing the utility for which they work, what is expected of them, and the benefits afforded them.

Each plant operator shall receive a copy of the manual of operations for the plant as prepared by the consulting engineer who designed the plant. If such a manual is not available, the utility should develop a manual for the plant operators.

At intervals of not more than 5 years, the utility should request the State to review personnel management and needs.

10.2.0 Organization(X-7,62)

A sound and definite plan of organization is essential to effective management of every water utility. Preparation of an organization manual is an excellent way to control and administer the organizational aspects of management. The manual should include a set of organizational charts for the utility and for each major division.

Generally, the line organization of a water utility would involve five functional divisions: (1) supply, (2) treatment, (3) distribution, (4) metering, and (5) billing and collection of accounts.

The staff organization would typically include: (1) legal, (2) accounting, (3) engineering, (4) personnel, and (5) public relations.

Management exercises control of all utility operations through establishment of policies, procedures, and budget.

10.3.0 Treatment Plant Staffing(X-2,62)

Operation of water treatment plants must rest in the hands of qualified persons. The number of employees in a particular plant depends upon a number of variable factors to be discussed in more detail later. One of the principal factors is that of plant size or capacity. Other important factors are the quality of raw water and the extent of treatment provided. For large plants, qualified operators should be present on every shift. For small plants, one qualified operator is usually responsible for the total operation, with the non-qualified operators following his strict instructions.

The AWWA handbook, "Water Quality and Treatment"(X-2) lists the following approximate staff requirements for surface water treatment plants.

Staff for 37.9 mLpd (10 mgd) Surface Water Treatment Plant

1 plant superintendent and chief operator
4 plant operators (one per shift, three shifts per day, four 42-hour work weeks)
1 maintenance mechanic
3 general utility help (duties would include chemical handling, grounds care, operator's vacation and holiday relief, mechanics helper, and basin cleaning)

9 Total

"A larger plant, 37.9 to 75.8 mLpd (10 to 20 mgd), may require an additional operator at each of the following stations: (1) the filter building, (2) the chemical feed room, (3) the low lift pumping station, and (4) the high-service pumping station. The maintenance staff would be proportional in size to the amount of equipment and grounds under its care."

Staff for 75.8 to 190 mLpd (20 to 50 mgd) Surface Water Treatment Plant on a Three-Shift, 42-Hour Week Basis

1 plant superintendent
1 assistant plant superintendent
3 chemists and bacteriologists
4 chemical building operators
4 high-service electric pumping station operators
1 stenographer
4 low-service pumping station operators
4 filter plant operators
2 basin men
5 maintenance mechanics
10 general utility helpers
1 supplies and storekeeper

40 Total

Plant size and capacity, the quality of raw water, and the extent of treatment provided have already been mentioned as factors which obviously are important in arriving at the number of employees needed to operate a water treatment plant. There are a number of other considerations worth mentioning, so that estimates of personnel requirements can be prepared or adjusted to suit local conditions.

10.3.1 Raw Water Quality and Unit Processes

The type of treatment which may be required as determined by raw water quality has been discussed in Section 2.2 of this Manual, which reveals the importance of this factor. A water utility disinfecting a ground water supply with chlorine obviously requires a much smaller operating staff than a utility which processes an equal amount of surface water. However, ground water supplies requiring chemical precipitation for iron or manganese removal may require nearly as many plant operators as a surface water treatment plant of comparable capacity.

10.3.2 Plant Layout

Plant layout and the relative placement of various unit processes and items of equipment affect operation and maintenance staffing because of the relative ease or difficulty of access afforded and because of the time required to walk from one work area to the next. Layout also affects yardwork, particularly if there are extensive areas of lawn, trees, flowers, and shrubs to be tended. These factors should be given detailed consideration by the engineering designer throughout planning and design of the plant. Once the plant is constructed, the operating utility can do little to change the work load and staffing which are inherent in the plant layout as built.

10.3.3 Disposal of Plant Wastes

As discussed earlier in Section 1.6 of this Manual, there is a wide variation in the means required for disposal of water treatment plant wastes. These requirements directly influence the operating and maintenance staff needed, which can vary from none for the simplest system to one or more operators per shift for the most complex.

10.3.4 Productivity of Labor

The productivity of employees can vary widely, and is almost entirely dependent on the skills, personalities, and philosophies of the policy makers and the manager. The desire to do a first class job, high morale, pride in the performance of the utility, and job satisfaction must start at the very top of the organization and permeate to every position in the organization chart if maximum productivity of all employees is to be achieved. If there is not a keen desire on the part of the governing board to spend the time, money, and effort required to do a good job, the tasks of the manager and staff become difficult if not impossible. This follows right down the organization line. One employee with no job interest or with low morale can ruin an entire crew or adversely affect performance of a whole division or utility. The difference between outstanding success and failure often hangs on a slender thread, which may break for lack of a spark of desire or interest somewhere along the line.

One item that deserves attention in maintaining employee morale is clear definition of areas of work responsibility, so that the work load is fairly shared by all and that some people are not overworked and others underworked. This task may become more difficult with increasing size of the utility due to greater complexity of staffing organization, and high morale may be easier to maintain in small utilities than in large ones.

10.3.5 Climate

The impact of climatic conditions on personnel engaged in operation and maintenance of water treatment plants can be offset to some extent, but not entirely, by good design. Exposure of personnel to extremes of heat and cold reduce individual productivity.

10.3.6 Training

It is fairly evident that good training makes a treatment plant staff more efficient. Many areas of water treatment are complex and require highly specialized knowledge and skills. Unfortunately the number of experts is small, and water utilities in the past have been reluctant to pay the salaries required to attract and hold the best qualified people available. Many water works employees should be highly qualified, and certified through a certification system developed and managed by the State.

Whatever the size of the staff, the selection of water works personnel should be made on the basis of education, experience, and dependability. Systems serving more than 10,000 population should employ or retain a professional engineer.

Many operation and maintenance chores must be learned on the job with hand-on training. Formal on-the-job training for new employees is a necessity. With the rapid advancement of treatment techniques to meet current day problems, a continuing education program for all employees is highly recommended. Such programs can be internal, or there are many special water works training courses available through junior colleges, universities, state health departments, AWWA, and EPA. The use of an operations manual for orientation and training prepared specifically for each plant is essential.

10.3.7 Automatic Sampling, Monitoring, and Control

As the number of automatic sampling and automatic monitoring and control stations increase, there is a need for more qualified operation and maintenance. Some savings in operations time due to automatic monitoring and control are offset by requirements for frequent repair and calibration involving relatively high maintenance and operator skills.

10.3.8 Outside Contracts for Work

Laboratory work, instrument and control system maintenance, and buildings and grounds maintenance are tasks that lend themselves to outside contracts. The laboratory tests for bacteria, virus, heavy metals, pesticides, organics, and other tests requiring special equipment are more often than not performed off-site by contract with a private or public health laboratory. Outside firms can compete quite well with in-house costs even in small plants for maintenance of buildings and grounds. Because special skills are required for instrument and control system maintenance, and because a full time technician may be be required or available, these chores are done by contract very satisfactorily in many instances.

10.3.9 Staffing Pattern

The organization of shift staffing and the amount of overtime paid can influence personnel costs greatly. Commonly, night and week-end staffing may be about one-third of weekday staffing. The needs for 24-hour, seven day staffing should be considered not only strictly from a cost standpoint but also with regard to possible effects on water quality and public health and safety. State health department requirements in this regard must be met.

10.3.10 Age and Condition of Equipment

These factors influence maintenance workload. Costs go up for old or improperly cared for equipment.

10.3.11 Operation at Less Than Design Flow

Water treatment plants and other water system components may require the same staff at less than design flow as at full design flow. When this is true, unit water production costs are obviously higher at low flows. This fact is often overlooked in preliminary planning estimates of unit production costs.

10.4.0 Suggested Training Programs (X-9) (VIII-9)

The likelihood of success of any training program starts with the selection of new employees with the best available aptitude, training, experience, and character for the work they are expected to do.

A well conceived, formal orientation of new employees is an essential part of any training program. Included in the orientation of each new employee should be information on employment conditions, duties, responsibilities, opportunities for advancement (career ladder), and benefits. Written copies of personnel policies and utility organization should be studied by the new employee and discussed by supervisors or instructors presenting the orientation lectures. New employees should receive technical instruction in the work they are to perform. Operators should complete a formal training course based on the material contained in the Plant Operations Manual which should be prepared by the consulting engineer who designed the treatment plant.

In-house on-the-job training programs should be developed on a formal basis for each position where this type of training appears advantageous.

The governing board of the utility and management should adopt a policy of encouraging and providing financial assistance to employees participating in refresher courses and special training courses, meeting, seminars, and schools conducted by AWWA, state health departments, EPA, private organizations, community colleges, universities, and the like.

Management should relate the acquisition of new skills to employee advancement and promotion and should clearly identify this relationship to each employee and should separate this from time merely spent on the job. Time spent on the job without development of better performance and greater knowledge is of little benefit to employer or employee so far as promotion is concerned.

10.5.0 Education, Training, and Experience(X-62)

The levels of education, training, and experience as related to water utility job categories are, in some cases, specifically spelled out, or mandated, in state certification laws, regulations, or programs. These, of course, must be followed where applicable. In any case, each utility should have as a part of its personnel document a series of job classification descriptions or job class specifications which relate training and experience qualifications to job categories. There are some efforts now underway in the water works industry to standardize these job classification requirements on a national basis. Until such requirements are standardized and universally adopted, if they are, each utility should set its own standards for the jobs within its organization.

To give examples of format and content of typical Job Class Specifications, descriptions of 21 classifications have been selected from the more than 260 total for the Denver, Colorado Board of Water Commissioners operations. These 21 job descriptions are presented as Appendix B of this Manual. These are typical of job descriptions for large utilities. They may be more specialized than those for smaller organizations, where one man may have a broader range of duties.

10.6.0 Certification(X-62)

Certification of water system operators is recommended. States should develop and implement certification plans.

Certification programs for operating personnel in water and/or wastewater facilities have been adopted on either mandatory or voluntary basis in more than 50 American and Canadian states and provinces. These programs have become an important link in the overall national effort to protect America's water resources and to provide a safe and adequate water supply. The U.S. Environmental Protection Agency (EPA) has recognized this fact through its support and encouragement of state certification programs, as shown by the activities of the Municipal Permits and Operations Division in the Office of Water Program Operations.

In each certification program, a key element is the classification system for facilities and personnel. For some time there has been a need to develop a sound foundation and improve the present classification systems. In addition, the existing diversity among programs has been recognized as a weakness and an obstacle to reciprocity. These points were made by state program representatives at the Organizational Meeting of the Association of Boards of Certification for Operating Personnel in Water and Wastewater Utilities (ABC) in June, 1972. The primary goal of ABC is to improve and strengthen certification efforts through communication and cooperation among the many certification programs in North America.

As its first project ABC undertook to study classification of facilities and personnel and to propose a standard system. The Office of Water Program Operations of EPA, with similar goals, recognized the newly organized ABC as the logical origin for such a study and offered to support the project with a federal grant. Agreement was reached and the grant was awarded on March 21, 1973.

By September, 1973 the assembling of basic data was complete and a draft proposal had been prepared and distributed among all state/provincial certification programs for review. The basic elements which were approved at the ABC Annual Meeting in October, 1973 are as follows:

1. Facility Classification

    a. Wastewater Treatment Plant (WWT)
    b. Wastewater Collection System (WWC)
    c. Water Treatment Plant (WT)
    d. Water Distribution System (WD)

Each category will have four(4) classes numbered from I to IV with IV being the highest.

2. Facility classification will be based upon a point system for treatment plants and a population/population equivalent system for the collection and distribution systems.

3. Operator Classification

    a. The system will parallel the facility classification system with an operator class for the superintendent level at each plant class.
    b. An operator-in-training class is also proposed.

4. Operator qualifications will be based upon experience, education and examination.

In addition, an examination procedure is proposed, based on a modular plan, separating questions by difficulty and into categories such as General, Hydraulics, Quality Control and Supervision/Management. A second grant project, awarded by EPA to ABC in March, 1974, is proceeding with the development of criteria for examinations.

To assure optimum acceptance of the system by existing programs, reviews and comments have been solicited at each stage of development, and the final result is the Classification System which is presented as Section II of the ABC report. It is believed that this is a workable system for water and wastewater certification programs, flexible enough for rapid implementation in varying degrees in different jurisdictions. It offers significant progress toward effective certification and at the same time provides a national standard by which individual classification systems may be measured.

It is recommended that:

1. Future certification programs and new programs under development should adopt the ABC classification system for personnel and facilities.

2. Existing certification programs should measure their current classification system beside the ABC system and determine the equivalence of classes to provide a reciprocity matrix.

3. Federal agencies with responsibilities for water and/or wastewater facilities should adopt the ABC classification system if they have none or determine its equivalency to their own system if one exists.

4. Existing and future certification programs should recognize the need for a career ladder in utility operations and management, and that the practice of certifying only the person "in responsible charge" is fast becoming obsolete. Personnel in charge of an operating shift should be certified at no less than one level below that of the plant superintendent, and all other operating personnel who may affect the quality of operation or final product should be certified at some level.

5. A similar comprehensive study should be undertaken by ABC to develop a classification system for industrial wastewater facilities and personnel. Very few existing certification programs give adequate recognition to the differences between such facilities and municipal wastewater treatment plants.

6. The project to develop specific examination criteria and a method of specialty certification, including implementation procedures, should be completed expeditiously.

7. Following 6 above, examinations should be developed based on the recommended criteria and should be made available for use by existing certification programs.

8. Guidance should be sought from the American Water Works Association (AWWA) and the Water Pollution Control Federation (WPCF) for establishing standards to determine the applicable training credit (T.C.) values for the educational requirements in the certification programs.

9. The line items and point values in the treatment facilities point systems should be reconsidered after 12 months exposure and field testing. With this experience modifications should be made as appropriate, subject to further adjustment as changing technology dictates.

10. To implement the desired improvements in certification programs, higher priority must be given to federal and state funding for the overall objectives of state certification.

10.7.0 Safety(X-10)

In the past, the safety record of the water works industry has not been good. It has, in fact, been one of the poorest for an industry. So there is a real need for effective safety programs in water utilities.

Adequately funded safety programs must be initiated and primarily directed by top management of the utility. An Executive Safety Committee should be formed. An employee safety education plan should be formulated.

A safety program has one direct objective, to prevent accidents. Accidents may be caused either by improper acts of employees or by hazardous conditions, or by a combination of both. It is possible to prevent accidents by determining causes and taking steps to eliminate them. Inspections, investigations, and tabulations are all part of the process of preventative action.

Establishment of a safety program by each utility is recommended. In establishing a safety program the first step is to clearly designate the persons who are to be responsible for the program. Lines of responsibility must be established. Secondly, adequate records must be kept. Third, an inspection system should be set up to detect unsafe conditions and practices. The safety program should be available to the state.

A suggestion program for safety improvement could be implemented to make personnel more safety concious.

A good traffic safety program must be developed to protect personnel and the general public from injury from work done by the water utility in the streets, and to minimize public inconvenience. All drivers should be taught safe driving practices.

SECTION X PERSONNEL

RATIONALE FOR PERSONNEL STANDARDS

10.1.0 Personnel - General

It is consistent with aims of this Manual which are to obtain better planning design, construction, operation, control and maintenance of public water systems, to devote some consideration to personnel matters. Attention to this most important facet of the overall problem could prove to be most productive because it is presently one area of weakness in water works management. There is room for great improvement in securing better qualified personnel, raising compensation levels, improving personnel practices, offering more in-service training, providing better and safer working conditions, and in bringing the overall personnel position of the water works industry up to date with that in other public and private endeavors.

The recommendations in these Standards are directed at accomplishing these worthy objectives.

10.2.0 Organization(X-7)

A plan of organization is essential to proper coordination of individual efforts to efficiently accomplish a common goal. Problems of coordination multiply as the numbers of people and activities increase and sound organization is increasingly important with size of the utility.

A definite good plan of organization can aid management in several ways. It can enable employees to understand their place in the overall effort, allow them to devote their full energies to discharge of their duties, and avoid duplication of effort and working at cross-purposes with others. There are several recognized principles of organization which apply to any enterprise including water utilities.

Management organization must be clearly defined, simple, realistic, flexible, and dynamic.

The main purposes of the business as a whole and of each division must be defined and understood. Line and staff activities should be integrated with and directed to basic objectives.

Organization plans and charts should be based upon the activities

Preceding page blank

to be performed and the objectives to be achieved, rather than to be built around an individual or group of individuals.

Each employee should have only one supervisor to whom he is directly responsible, and all direction and guidance should be channeled through this one supervisor to the employee.

The number of people assigned to a single supervisor should be held to the lowest possible figure.

The number of levels of management above the work level should also be held to a minimum to avoid misunderstanding and to provide more effective direction of efforts.

Authority should be delegated to the lowest possible level in the organization, and decisions should be made as close as possible to the required action.

Responsibility and authority to act are two duties which must be clearly defined and understood by supervisor and employee alike.

Supervisory authority (organizational line functions) must not be violated or weakened by staff functions. All orders to employee for staff as well as line work should be channeled through the employees direct supervisor.

Organizational plans must be tailored to the specific requirements of each individual enterprise.

10.3.0 Treatment Plant Staffing(X-62)

Proper operation and control of water treatment facilities are key factors in meeting Federal Drinking Water Standards and public expectations of good water quality. The deplorable fact that a great many public water supply systems fail to meet either the minimum Federal Standards or public approval, much less to even higher standards of water quality which are readily attainable, points to the need to improve the quality and perhaps also the quantity of treatment plant staffing.

These Standards provide guidelines to the needs in this area, some of the variable which apply to different situations, and potential solutions to staffing problems.

10.4.0 Suggested Training Program

These Standards are prepared in response to a need for better preparation and continuing improvement of water system employees. Much of the training for water works employees is of necessity going to take place in-house through each utility's own efforts with the aid of engineering consultants and teaching specialists.

The opportunities for general formal training and outside specialized training in the water works field differ from place to place. Perhaps these opportunities can best be outlined by use of a specific example. Beginning on Page 68 of the September, 1974 issue of Public Works Magazine is an article entitled, "Training and Certification of Water and Wastewater Personnel". This article summarizes the training facilities and arrangements in Texas as follows: (1) Area schools conducted by the Engineering Extension Service of Texas A & M University. These consist of 20 class-hours each and are offered in all areas of the state by eleven full-time instructors. Some 2,700 people enroll each year. (2) Seven three-day short courses are sponsored annually by the Texas Water Utilities Association in cooperation with the State Department of Health, Texas Water Quality Board and local municipalities. About 2,800 attend each year. (3) The Texas State Technical Institute, a technical and vocational school offers one and two-year courses on water and wastewater technology, in addition to several week-long special courses, such as in laboratory procedures. (4) Nationally recognized correspondence courses are evaluated and approved for training credits. Employers are encouraged to reimburse the students after completion. (5) There are 42 district associations of water and wastewater utility personnel located throughout the state. These meet monthly and have planned programs. Attendance varies with each, between 20 and 200. (6) Federal funds have been used by the Texas Water Quality Board and certain government agencies to offer training in various areas. In the last year or two, these have been coordinated into the overall training activities. (7) One semester courses are offered in water and wastewater technology in the 11th grade with co-op work in the 12th grade to 200 students at present.

There are similar opportunities for operator training in other states.

10.5.0 Education, Training, and Experience

This Section of these Standards give the relationships between education, experience, and training and various job categories in the water utility field. There are efforts to standardize requirements along this line on a national basis. Again, this subject is perhaps best illustrated by the 21 examples of job descriptions and qualifications selected for presentation in Appendix B to this Manual.

10.6.0 Certification

The Standards in this Manual are not original, they are basically a summary of the work which has been done by the ABC, AWWA, WPCF, the Conference of State Sanitary Engineers, state health departments, and others who have been active in this area.

10.7.0 Safety

Safety practices and safety programs for the water works industry have been developed largely through the efforts of the AWWA. The Standards in this Manual are a summary of the latest AWWA recommendations in this regard. For further details refer to AWWA Manual No. M3, "Safety Practices for Water Utilities, 1971" and to OSHA regulations.

BIBLIOGRAPHY

SECTION I GENERAL DESIGN CONSIDERATIONS

1. Albrecht, A.E., "Disposal of Alum Sludges", JAWWA, p. 46, Jan. 1972.

2. ASCE, Manuals of Engineering Practice No. 19, "Water Treatment Plant Design", ASCE, 1940.

3. ASCE, AWWA, CSSE, "Water Treatment Plant Design", AWWA, 1969.

4. AWWA Research Foundation Report, "Disposal of Waters From Water Treatment Plants", JAWWA, Part 1, p. 541, October 1969, Part 11, p. 619, November 1969, Part 111, p. 709, December 1969, Part IV, p. 63, January 1970.

5. AWWA Committee Report, "Disposal of Water-Treatment-Plant Wastes", JAWWA, p. 814, December 1972.

6. AWWA, "Regionalization of Water Systems", AWWA Research Foundation, Public Water Supply Treatment Technology, p. 15, 1973.

7. Bacon, V.W., "Impact of Environmentalism on Water-Utility Operation", JAWWA, p. 383, June 1973.

8. Barlow, J.H., "Sludge Handling and Disposal", JAWWA, p. 345, June 1973.

9. Benn, D., and Bridge, L., "Sludge Disposal by Pressing", Journal of the Institution of Water Engineers, p. 417, November 1971.

10. Black, A.P., Shuey, B.S., and Fleming, P.J., "Recovery of Calcium and Magnesium Values", JAWWA, p. 616, October 1971.

11. Black, A.P. and Singley, J.E., "Water Quality and Treatment, Past, Present, and Future", JAWWA, p. 6, January 1972.

12. Brunold, W.H. and Ward, P.C., "Consumer Assessment of Water Quality and the Cost of Improvements", JAWWA, p. 3, January 1971.

13. Burgess, L.C.N., "Water for the Year 2000", JAWWA, p. 211, April 1970.

14. Clapper, L.S., "The Environment and Water-Resource Development", JAWWA, p. 291, May 1974.

15. Culp, G.L. and Culp, R.L., "Improving Water Quality In A Changing Environment", Chapter 1, p. 1, New Concepts in Water Purification, Van Nostrand Reinhold, New York, 1974.

16. Culp, R.L. and Culp, G.L., Advanced Wastewater Treatment, Van Nostrand Reinhold, New York, 1971.

17. Dean, R.B., "Disposal of Wastes From Filter Plants and Coagulation Basins", JAWWA, p. 1226, November 1953.

18. De Filippi, J.A., "Designing Filtration Plant Waste-Disposal Systems", JAWWA, p. 185, March 1972.

19. De Marco, T.C., "Gas-Turbine Standby Power Generation for Water Treatment Plants", JAWWA, p. 133, February 1974.

20. Fair, G.M., Geyer, J.C., and Morris, J.C., "Water Supply and Wastewater Disposal", John Wiley & Sons, New York, 1959.

21. Farrell, J.B., Smith, J.E., Dean, R.B., Grossman, E., and Grant, O.L., "Natural Freezing for Dewatering of Aluminum Hydroxide Sludges", JAWWA, p. 787, December 1970.

22. Fulton, G.P., "Recover Alum to Reduce Waste-Disposal Costs", JAWWA, p. 312, May 1974.

23. Fulton, G.P., "Alum Recovery for Filtration Plant Waste Treatment", Water and Wastes Engineering, p. 78, June 1970.

24. Fulton, G.P., "Disposal of Wastewater From Water Filtration Plants", JAWWA, p. 323, July 1969.

25. FWPCA, National Technical Advisory Committee Report, "Raw-Water Quality Criteria for Public Supplies", JAWWA, p. 133, March 1969.

26. Gates, C.D., and McDermott, R.F., "Characterization and Conditioning of Water Treatment Plant Sludge", JAWWA, p. 33, March 1968.

27. Geldrich, E.E., Nash, H.D., Reasoner, D.J., and Taylor, R.H., "The Necessity of Controlling Bacterial Populations in Potable Waters: Community Water Supply", JAWWA, p. 596, September 1972.

28. Glenn, R.W., Judkins, J.F. Jr., and Morgan, J.M., "Filtrability of Water Treatment Plant Sludge", JAWWA, p. 414, June 1973.

29. Goldman, C.R., "Environmental Impact & Water Development", JAWWA, p. 545, September 1972.

30. Great Lakes-Upper Mississippi River Board of State Sanitary Engineers, "Recommended Standards for Water Works", 1968 Edition with 1972 revisions.

31. Hardenburgh, W.A., "Water Supply and Purification", International Textbook Press, Scranton, Pa., 1945.

32. Hawkins, F.C., Judkins, J.F., Jr., and Morgan, J.M., "Water-Treatment Sludge Filtration Studies", JAWWA, p. 653, November 1974.

33. Hubbs, S.A., and Pavoni, J.L., "Optimization of Sledge Dewaterability in Sludge-Disposal Lagoons", JAWWA, p. 658, November 1974.

34. Inhoffer, W.R., and Doe, P.W., "Design of Wash-Water and Alum-Sludge Disposal Facilities", JAWWA, p. 404, June 1973.

35. Jardine, J.W. and Howson, L.R., "Advance Planning Success In Chicago", JAWWA, p. 397, July 1970.

36. Jones, R.L., "Environmental-Impact Assessment for Plant Design and Operation", JAWWA, p. 287, May 1974.

37. Krasauskas, J.W., "Review of Sludge Disposal Practices", JAWWA, p. 225, May 1969.

38. Krause, K.S., "Water Problems & Planning in Kansas", JAWWA, p. 376, June 1970.

39. Krieger, J.H., "Legal Aspects of Environmentalism", JAWWA, p. 532, August 1973.

40. Larkin, D.G. and Anton, W.F., "Environmental Assessment of Water-System Improvements", JAWWA, p. 282, May 1974.

41. Lee, Roger D., "Protecting Community Water Supplies", JAWWA, p. 216, April 1972.

42. Logsdon, G.A., and Edgerley, E., "Sludge Dewatering by Freezing", JAWWA, p. 734, November 1971.

43. Long, W.N. and Bell, F.A., Jr., "Health Factors and Reused Water", JAWWA, p. 220, April 1972.

44. Mahoney, P.F., and Duensing, W.J., "Precoat Vacuum Filtration and Natural-Freeze Dewatering of Alum Sludge", JAWWA, p. 665, October 1972.

45. McCabe, L.J., Symons, J.M., Lee, R.D., and Robeck, G.G., "Survey of Community Water Supply Systems", JAWWA, p. 670, November 1970.

46. McKee, J.E. and Rice, T.R., "Clouds in the Crystal Ball", JAWWA, p. 265, May 1974.

47. Neubauer, W.K., "Waste Alum Sludge Treatment", JAWWA, p. 819, July 1968.

48. Nielson, H.L., Carns, K.E., and DeBoice, J.N., "Scroll Centrifuge for Dewatering Wins at One Plant", Water and Wastes Engineering, p. 44, March 1973.

49. Nielsen, H.L., et al. "Alum Sludge Thickening and Disposal", JAWWA, p. 385, June 1973.

50. Okun, D.A., "Alternatives in Water Supply", JAWWA, p. 215, May 1969.

51. Pentecost, F.C., "Design Guidelines for Distribution Systems", JAWWA, p. 333, June 1974.

52. Piersall, C.H. and Platt, S.F., "Water-Capacity Planning for Metropolitan Areas", JAWWA, p. 89, February 1971.

53. Remus, Gerald, "Building Reliability of Plant, People, and Service", JAWWA, p. 38, January 1970.

54. Richl, M.L., "Hoover's Water Supply and Treatment", National Lime Association, Washington, D.C., 1957.

55. Roberts, J.M., and Roddy, C.P., "Recovery and Reuse of Alum Sludge at Tampa", JAWWA, p. 857, July 1960.

56. Roberts, W.J., Csallany, S.C., and Towery, N.G., "Forecasting Water Demands and Systems Capabilities", JSED, ASCE, SA6, p. 1349, December 1970.

57. Schwoyer, W.L., and Luttinger, L.B., "Dewatering of Water-Plant Sludges", JAWWA, p. 399, June 1973.

58. Seeger, W.R., "Project Interference by Environmentalists", JAWWA, p. 538, August 1973.

59. Seidel, H.F., "Trends in Residential Water Use", JAWWA, p. 490, September 1969.

60. State Standards for Water Works, Alaska, Arizona, California, Connecticut, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Louisiana, Maine, Maryland, Massachusetts, Michigan, Missouri, Mississippi, Montana, Nebraska, Nevada, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, Tennessee, Texas, Utah, Virginia, Vermont, Washington, and Wisconsin.

61. Streicher, L., "Filter Backwash Gets Special Treatment", The American City, p. 94, November 1967.

62. Sutherland, E.R., "Treatment Plant Waste Disposal in Virginia", JAWWA, p. 186, April 1969.

63. Thompson, C.G., Singley, J.E., and Black, A.P., "Magnesium Carbonate -- A Recycled Coagulant", JAWWA, Part 1, p. 11, p. 93, January and February 1972.

64. Townsend, J.R., "What the Wastewater Plant Engineer Should Know About Centrifuges", Water and Wastes Engineering, November, December, 1969.

65. U. S. Army, Corps of Engineers, "Engineering Manual for Water Department Construction", Part VII, Chapter 1, February 1946.

66. Vogt, J.E., "Impact of Wastewater Discharges on Surface Water Sources", JAWWA, p. 113, February 1972.

67. Wang, C.K., et al, "Continuous Pilot-Plant Study of Recycling Filter Backwash Water", JAWWA, p. 355, May 1973.

68. Wanielista, M.P. and Falkson, L.M., "Flexibility in Water Treatment Plant Design", JAWWA, p. 281, May 1971.

69. Walton, Graham, "Relation of Treatment Methods to Limits for Coliform Organisms in Raw Water", JAWWA, p. 1281, October 1956.

70. Weir, P., "Research Activities by Water Utilities - Atlanta Water Dept.", JAWWA, p. 634, October 1972.

71. Westerhoff, G.P. and Daly, M.P., "Water-Treatment-Plant Wastes Disposal - Part 1", JAWWA, p. 319, May 1974.

72. White, W.J., "A Centrifugal For Industrial Wastes", Chemical Engineering Progress, June 1969.

73. Wilford, John, "Legal Aspects of New Jersey Potable Water Program", JAWWA, p. 193, April 1969.

74. Williams, N.C. and Redfern, J.M., "The Financial Feasibility of Regionalization", JAWWA, p. 159, March 1973.

75. Woodward, R.L., "Relation of Water Quality To Treatment Plant Design", JAWWA, p. 432, 1964.

BIBLIOGRAPHY

SECTION II SOURCE DEVELOPMENT

1. AWWA, "Quality Goals for Public Water", Statement of Policy, JAWWA, p. 1317, 1968.
2. "AWWA Manual M-13, Spillway Design Practice", AWWA, Denver, Colorado, 1964.
3. "AWWA Standard for Deep Wells, AWWA A100-66", AWWA, Denver, Colorado, 1966.
4. AWWA Manual No. 21, "Groundwater", AWWA, Denver, Colorado, 1973.
5. Arceneaux, W., "Operation and Maintenance of Wells", JAWWA, p. 199, March 1974.
6. Argo, David, G., and Culp, G.L., "Heavy Metals Removal in Wastewater Treatment Processes", Water and Sewage Works, Part I, p. 62, August 1972, Part II, p. 128, September 1972.
7. ASCE, Manuals of Engineering Practice No. 19, "Water Treatment Plant Design", ASCE, 1940.
8. ASCE, AWWA, CSSE, "Water Treatment Plant Design", AWWA, 1969.
9. AWWA, "Water Quality and Treatment", McGraw Hill Book Co., New York, 1971.
10. Babbitt, H.E., and Doland, J.J., "Water Supply Engineering", McGraw Hill Book Co., New York, 1939.
11. Ballack, E., "Arsenic Removal From Potable Water", JAWWA, p. 454, July 1971.
12. Bills, et al., "Sodium and Potassium in Foods and Waters", J. Amer. Dietetic Assoc., p. 304, 1949.
13. Bouwer, H., "Renovating Municipal Wastewater by High-Rate Infiltration for Ground-Water Recharge", JAWWA, p. 159, March 1974.
14. Cheremisinoff, P.N., and Habib, Y.H., "Cadmium, Chromium, Lead, Mercury: A Plenary Account for Water Pollution", Water and Sewage Works, p. 47, August 1972.
15. Culp, G.L. and Culp, R.L., "Chapter 7, Heavy Metal Removal", New Concepts in Water Purification, Van Nostrand Reinhold Co., New York, 1974.

16. Culp, R.L., "Disease Due to 'Nonpathogenic' Bacteria," JAWWA, p. 157, 1969.

17. Culp, R.L., "Possible Effects of Drinking High-Sodium Waters on Patients Under Restricted Sodium Therapy", Kansas State Board of Health Bulletin, 1954.

18. EPA, "Manual for Evaluating Public Drinking Water Supplies", EPA, 1971.

19. Esmond, S.E., and Petrasck, A.C. Jr., "Trace Metal Removal", Industrial Water Engineering, p. 14, May/June 1974.

20. Ettinger, M.B., "A Proposed Toxicological Screening Procedure for Use in the Water Works", JAWWA, p. 689, 1960.

21. Fair, G.M., Geyer, J.C., and Morris, J.C., "Water Supply and Wastewater Disposal, John Wiley and Sons, 1959.

22. Federal Radiation Council, "Radiation Protection Guidance for Federal Agencies", Federal Register, May 18, 1960.

23. Federal Radiation Council, "Radiation Protection Guidance for Federal Agencies", Federal Register, September 26, 1961.

24. FWPCA, "Enzyme Detergents in Water Supplies", JAWWA, p. 640, 1969.

25. Goldshmid, J., "Water Quality Aspects of Ground Water Recharge in Israel", JAWWA, p. 163, March 1974.

26. "Groundwater Pollution and Conservation", Env. Science and Technology, p. 213, March 1972.

27. Hardenbergh, W.A., "Water Supply and Purification", International Textbook Co., Scranton, Pa., 1945.

28. "How Much Metal Is There in Our Waters", Env. Science and Technology, p. 112, February 1974.

29. Johnson, E.E., "Ground Water, Its Development, Uses, and Conservation", H.M. Smyth Printing Co., St. Paul, Minnesota, 1947.

30. Kaufman, W.J., "Chemical Pollution of Ground Waters", JAWWA, p. 152, March 1974.

31. Lee, Roger D., "Protecting Community Water Supplies", JAWWA, p. 216, April 1972.

32. Lieber, M. et al., "Cadmium and Hexavalent Chromium in Nassau County Ground Water", JAWWA, p. 739, 1964.

33. Long, William N., and Bell, F.A., Jr., "Health Factors and Reused Waters", JAWWA, p. 220, April 1972.

34. Lowe, H. and Freeman, G., "Boron Hydride (Borane) Intoxication in Man", AMA Archives of Industrial Health, p. 523, 1957.

35. "Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water For Occupational Exposure", NBS Handbook 69 as amended August 1963, U.S. Department of Commerce.

36. McCabe, L.J., Symons, J.M., Lee, R.D., and Robeck, G.G., "Survey of Community Water Supply Systems", JAWWA, p. 670, November 1970.

37. McCullough, C.A., "Managing Water Resources From the Wrong Place at the Wrong Time", JAWWA, p. 187, March 1974.

38. McKee, J.E., and Wolf, H.W., "Water Quality Criteria", Calif. State Water Quality Control Board, Publ. 3-A, 1963.

39. McKane, C.E., et al. "Rapid Uptake of Mercuric Ion by Goldfish", Env. Science and Technology, p. 1138, November 1971.

40. Metzler, D.F. and Stoltenberg, H.A., "The Public Health Significance of High Nitrate Waters As A Cause of Infant Cyanosis and Methods of Control", Transactions of the Kansas Academy of Science, 1950.

41. Moore, Edward W., "Physiological Effects of the Consumption of Saline Drinking Water", Progress Report to the Subcommittee on Water Supply, National Research Council, 1952.

42. Nilsson, R., "Removal of Metals by Chemical Treatment of Municipal Wastewater", Water Research, 5, p. 51, 1971.

43. N.Y.S.D.H. Bulletin No. 22, "Water Supply Control", N.Y. State Dept. of Health, 1962.

44. Pomeroy, R.D., "Problems of Water-Quality Standards in the Management of Ground Water Basins", JAWWA, p. 143, March 1974.

45. Princi, F., Metals-Cadmium in Oxford Loose Leaf Medicine, Vol. IV, Chap. XI, New York, 1949.

46. Pringle, B.H., Hissange, D.E., Katz, E.L., and Mulawka, S.T., "Trace Metal Accumulation by Estaurine Mollucks", J. San. Eng. Div., 94, p. 455-473, 1968.

47. Report of the Joint Program of Studies on the Decontamination of Radioactive Waters, ORNL-2557, TID-4500 (14th Ed.) Oak Ridge National Laboratory, Robert A. Taft Sanitary Engineering Center, February 1959.

48. Riehl, M.L., "Hoover's Water Supply and Treatment", National Lime Association, Washington, D.C., 1957.

49. Russell, E.L., "Sodium Imbalance in Drinking Water", JAWWA, p. 102, 1970.

50. Schmidt, K.D., "Nitrates and Ground-Water Management in the Fresno Urban Area", JAWWA, p. 146, March 1974.

51. Sigworth, E.A., and Smith, S.B., "Adsorption of Inorganic Compounds by Activated Carbon", JAWWA, p. 386, June 1972.

52. Singley, J.E., and Black, A.P., "Water Quality and Treatment! Past, Present, and Future", JAWWA, p. 6, January 1972.

53. Smith, O.M., "The Detection of Poisons in Public Water Supplies", Water Works Engr., p. 1293, 1944.

54. Stanley, W.E., "Notes on Water Supply In North African Campaign", J. New Eng. WW Assoc. Vol. LVIII, No. 4, 1944.

55. State Standards for Water Works, Alaska, Arizona, California, Connecticut, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Louisiana, Maine, Maryland, Massachusetts, Michigan, Missouri, Mississippi, Montana, Nebraska, Nevada, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, Tennessee, Texas, Utah, Virginia, Vermont, Washington, and Wisconsin.

56. Stoltenberg, D.H., "How to Reclaim a Poisoned Lake", Public Works, p. 59, March 1972.

57. Storrs, P.N., "Toxicological Significance of Arsenic in Drinking water", Special Report U.S. Public Health Service, Feb. 2, 1962.

58. Straub, C.P. et al, "Strontium-90 in Surface Waters in the U.S.," JAWWA, p. 756, 1960.

59. Taylor, Floyd B., "Trace Elements and Compounds in Waters", JAWWA, p. 728, 1971.

60. Thomas, H.E., "The Conservation of Ground Water", McGraw Hill, New York, 1961.

61. Todd, D.K., "Salt Water Intrusion and Its Control", JAWWA, p. 180, March 1974.

62. Toups, J.M., "Water Quality and Other Aspects of Ground-Water Recharge in Southern California", JAWWA, p. 149, March 1974.

63. U.S.P.H.S., "Effectiveness of Water Treatment Processes as Measured by Coliform Reduction", Publication No. 898, U.S. Public Health Service, 1957.

64. U.S.P.H.S. Public Health Bulletin No. 296, "Manual of Recommended Water-Sanitation Practice", U.S. Public Health Service, 1946.

65. Vogt, J.E., "Impact of Wastewater on Surface Water Sources", JAWWA, p. 113, February 1972.

66. Winton, E.F., and McCabe, L.J., "Studies Relating to Water Mineralization and Health", JAWWA, p. 26, 1970.

67. Winton, E.F., Tardiff, R.G., and McCabe, L.J., "Nitrate in Drinking Water", JAWWA, p. 95, 1971.

68. WHO, "Reuse of Effluents: Methods of Wastewater Treatment and Health Safeguards", World Health Organization Technical Report Series No. 517, WHO, Geneva, 1973.

69. Woodward, R.L., "Raw Water Quality Criteria for Public Supplies", JAWWA, p. 133, March 1969.

70. Zemansky, G.M., "Removal of Trace Metals During Conventional Water Treatment", JAWWA, p. 606, October 1974.

71. U.S.P.H.S., "Drinking Water Standards, 1962", U.S. Dept. of Health, Education, & Welfare, 1962.

72. EPA, "Interim Primary Drinking Water Standards",March 14, 1975.

BIBLIOGRAPHY

SECTION III TREATMENT

1. Abel, F.H., and Tihansky, D.P., "Methods and Problems of Estimating Water - Quality Benefits", JAWWA, p. 276, May 1974.

2. Alley, L.A., "Water Plant Capacity Doubled Without Additional Construction", Public Works, p. 106, February 1965.

3. ASCE, AWWA, CSSE, "Water Treatment Plant Design", AWWA, 1969.

4. AWWA, "Water Quality and Treatment", McGraw-Hill Book Co., New York, 1971.

5. Bean, E.L., "Progress Report on Water Quality Criteria", JAWWA, p. 1313, 1962.

6. Camp, "Water and Its Impurities", Van Nostrand Reinhold Co., New York, 1963.

7. Clarke, N.A., Berg, G., Liu, O.C., Metcalf, T., Sullivan, R. and Vlassoff, L., "Committee Report, Viruses in Water", JAWWA, p. 491, 1969.

8. Clarke, N.A., Berg, G., Kabler, P.W., and Chang, S.L., "Hunman Enteric Viruses in Water: Source, Survival and Removability", Advances in Water Pollution Research, Proc. Int. Conf., London, 1962, Vol. 2, Pergamon Press, London, 1964.

9. Cox, C.R., "Laboratory Control of Water Purification", Case-Sheppard-Mann Publ. Corp., New York, 1946.

10. Culbreath, M.C., "Necessary Modifications for High Rate Filtration", JAWWA, p. 699, June 1968.

11. Culbreath, M.C., "Experience with Multimedia Filter", JAWWA, p. 1014, August 1967.

12. Culp, G.L., Hansen, S.P., and Richardson, G.H., "High Rate Sedimentation in Water Treatment Works", JAWWA, p. 681, 1968.

13. Culp, G.L., Hsiung, A., and Conley, W.R., "Tube Clarification Process, Operating Experiences", JSED, ASCE, SA5, p. 829, October 1969.

14. Culp, G.L., and Culp, R.L., "New Concepts in Water Purification", Van Nostrand Reinhold Co., New York, 1974.

15. Culp, R.L., and Culp, G.L., "Advanced Wastewater Treatment", Van Nostrand Reinhold Co., New York 1971.

16. Culp, R.L., "New Water Treatment Methods Serve Richland", Public Works, p. 86, July 1964.

17. EPA, "Manual for Evaluating Public Drinking Water Supplies", EPA, 1971.

18. Fair, G.M., Geyer, J.C. and Morris, J.C., "Water Supply and Wastewater Disposal", John Wiley & Sons, 1959.

19. Garel, T.V., "Depth Filters Do Double Duty", Water and Wastes Engineering, p. 34, December 1965.

20. Great Lakes-Upper Mississippi River Board of State Sanitary Engineers, "Recommended Standards for Water Works", 1968 Edition with 1972 Revisions.

21. Hanse, S.P., Richardson, G.N., Hsiung, A., "Some Recent Advantages in Water Treatment Technology", Chemical Engineering Progress Symposium Series, p. 207, 1969.

22. Harris, G.A., and Ringwood, R.J., "Water Needs Met by High Rate Sedimentation and Filtration", Public Works, p. 65, January 1970.

23. Hudson, H.E., Jr., "High Quality Water Production and Viral Disease", JAWWA, p. 1265, 1962.

24. Kay, G.H., "Asbestos in Drinking Water", JAWWA, p. 513, September 1974.

25. LaFontaine, E.O., "Advanced Engineering Technology for Uprating Treatment Plants", JAWWA, p. 59, January 1974.

26. Laughlin, J.G., and Duvall, T.E., "Simultaneous Plant-Scale Tests of Mixed-Media and Rapid Sand Filters", JAWWA, p. 1015, September 1968.

27. Livingston, A.P., "High Rate Treatment Evaluated at Buffalo Pound Filtration Plant", Water and Sewage Works, June 1970.

28. McCabe, L.J., Symons, J.M., Lee, Roger D., and Robeck, G.G., "Survey of Community Water Supply Systems", JAWWA, p. 670, 1970.

29. McKinney, "Microbiology for Sanitary Engineers", McGraw Hill Book Co., New York, 1962.

30. Olson, H.L., "Asbestos in the Potable-Water Supplies", JAWWA, p. 515, September 1974.

31. Pluntze, James C., "Water Utilities -- A Victim of Success", JAWWA, p. 551, 1971.

32. Riddle, W.G., "Modernizing Water Filtration Plants", Public Works, p. 86, June 1974.

33. Riehl, M.L.,"Hoover's Water Supply and Treatment", Nat'l Lime Assoc., Wash., D.C., 1957.

34. Robeck, G.G., Clarke, N.A., and Dostal, K.A., "Effectiveness of Water Treatment Processes in Virus Removal", p. 1275, 1962.

35. Lawyer and McCarty, "Chemistry for Sanitary Engineers", McGraw Hill Book Co., New York, 1967.

36. Sedore, J.K., "We Converted to High Rate Filtration", American City, April 1968.

37. Sorber, C.A., Malina, J.L., Jr., and Sagik, B.P., "Quantilative Procedure for Evaluating the Performance of Water and Wastewater Treatment Processes at Naturally Occurring Virus Levels", Env. Science and Technology, p. 438, May 1972.

38. Spink, C.M., and Monscvitz, J.T., "Design and Operation of a 200 mgd Direct Filtration Facility", presented at the 1973 AWWA Conference, Las Vegas, Nevada, May 14, 1973.

39. Sproul, O.J., "Virus Inactivation by Water Treatment", JAWWA, p. 31, January 1972.

40. Streicher, L., "Treatment Plant Design", JAWWA, p. 629, November 1974.

41. Taylor, F.B., "Viruses-What is Their Significance in Water Supplies", JAWWA, p. 306, May 1974.

42. Texas Water Works and Sewerage Short School, "Manual for Water Works Operators", Texas State Dept. of Health, Austin, Texas, 1951.

43. U.S. Public Health Service, "Manual for Protection of Public Water Supplies from Chemical Agents", U.S. Public Health Service Publ. No. 1071-j1, May 1966.

44. Vander Velde, T.L., and Mark, W.N., "Poliovirus in a Water Supply", JAWWA, p. 345, May 1973.

45. Viraraghavan, T., "Water Quality and Human Health", JAWWA, p. 647, October 1973.

46. Walling, F.B., et al, "Federal Research in Potable-Water Technology", JAWWA, p. 616, October 1972.

47. Wallis, C., Hommia, A., Melnick, J.L., "Apparatus for Concentrating Viruses from Large Volumes", JAWWA, p. 189, March 1972.

48. Walton, Graham, "Emergency Treatment for Reducing Concentrations of Specific Chemicals in Public Water Supplies", Nat. Water Supply Res. Lab., 1968.

49. Westerhoff, G.P., "Expansion of Suburban Buffalo Filtration Plant", Water and Wastes Engineering, p. 68, June 1970.

50. Wolf, H.W., Safferman, R.S., Mixson, A.R., and Stringer, C.E., "Virus Inactivation During Tertiary Treatment", JAWWA, p. 526, September 1974.

51. Anon., "Studies on Trace Metals", Env. Science & Technology, p. 684, August 1973.

52. Argo, D.G., and Culp, G.L., "Heavy Metals Removal in Wastewater Treatment Processes", Water and Sewage Works, p. 62, August 1972, and p. 128, September 1972.

53. Barth, E.F.,Ettinger, M.B., Salotto, B.V., and McDermott, J.N., "Summary Report on the Effects of Heavy Metals on Biological Treatment Processes", JWPCF, p. 1, 86, January 1965.

54. Barth, E.F., English, J.N., Salotto, B.V., Jackson, B.N., and Ettinger, M.B., "Field Survey of Four Municipal Wastewater Treatment Plants Receiving Metallic Wastes", JWPCF, p. 1101, August 1965.

55. Bellack, E., "Arsenic Removal from Potable Water", JAWWA, p. 454, July 1971.

56. Cangelose, J.T., "Acute Cadmium Metal Poisoning", U.S. Navy Med. Bull., p. 39 and 408, 1941.

57. Davids, H.W., and Lieber, M., "Underground Water Contamination by Chromium Wastes", Water and Sewage Wks., p. 528, 1951.

58. Derby, R.L., "Methods of Testing and Significance of Boron in Water", JAWWA, p. 1449, 1936.

59. Eaton, F.M., "Boron in Soils and Irrigation Waters and Its Effects on Plant", Tech. Bull. 448, USDA, Wash., D.C., 1935.

60. Feitknecht, W., and Schindler, P., "Solubility Constants of Metal Hydroxide Salts in Aqueous Solution", IUPAC Pure and Applied Chemistry, 6, p. 180, 1963.

61. Goldblatt, E.L., Van Denburgh, A.S., and Marsland, "The Unusual and Widespread Occurrence of Arsenic in Well Waters of Lane County, Oregon", Lane County, Oregon Health Dept., 1963.

62. Gulledge, J.H., and O'Conner, J.T., "Removal of Arsenic From Water by Adsorption on Aluminum and Ferric Hydroxides", JAWWA, p. 548, August 1973.

63. Goudey, R.F., "Solving Boron Problems in Los Angeles Water Supply", Western Construction News, p. 275, 1936.

64. Hammerstrom, R.J., et al, "Mercury in Drinking Water Supplies", JAWWA, p. 60, January 1972.

65. Hem, J.D., and Durum, W.H., "Solubility and Occurrence of Lead in Surface Water", JAWWA, p. 562, August 1973.

66. Homer, Jackson, Thurston, "Industrial Waste Treatment Practice", Butterworths Associated with Imp. Chem. Ind. Ltd., 1961.

67. Humenick, M.J. Jr., and Schnoor, J.L., "Improving Mercury (II) Removal by Activated Carbon", JEED, ASCE, p. 1231, December 1974.

68. Jenkins, S.H., Keight, D.G., and Humphrey, R.E., "The Solubility of Heavy Metal Hydroxides in Water, Sewage, and Sewage Sludge--1, The Solubility of Some Metal Hydroxides", Int. J. Air Wat. Poll., 8, p. 537-556, 1964.

69. Kantawala, D., and Tomlinson, H.D., "Comparative Study of Recovery of Zn and Ni by Ion Exchange Media and Chemical Precipitation", Water and Sewage Works R280, 1964.

70. Jenkins, S.H., Keight, D.G., and Ewins, A., "The Solubility of Heavy Metal Hydroxides in Water, Sewage, and Sewage Sludge--II, The Precipitation of Metals by Sewage", Int. J. Air. Wat. Poll. 8, p. 679-693, 1964.

71. Kubota, J., "Lead, Cd, Zn, Cu and Co in Streams and Lake Waters of Cayuga Lake Basin, N.Y.", Env. Science & Techrology, p. 243, March 1974.

72. Latimer, W.M., The Oxidation States of the Elements and Their Potentials in Aqueous Solutions, 2d ed, Prentice-Hall, Inc., Englewood Cliffd, N.J., 1952.

73. Lieber, M. and Welsch, W.F., "Contamination of Ground Water by Cadmium", JAWWA, p. 51, 1954.

74. Lindstedt, D.K., and Kruger, Paul, "Vanadium Concentrations in Colorado River Basin Waters", JAWWA, p. 85, 1969.

75. Lindstedt, D.K., and O'Connor, J.T., University of Colorado and Illinois, Behavior of Trace Elements in Water Reclamation Treatment Processes, Build Cooperative Research Reports, August 1969.

76. Logsdon, G.S., and Symons, J.M., "Mercury Removal by Conventional Water Treatment Techniques", JAWWA, p. 544, August 1973.

77. McElhoney, H.W., "Metal-Finishing Wastes Treatment at the Meadville, Pa. Plant of Talon, Inc.", Sewage and Industrial Wastes, Vol. 25, No. 4, p. 475, April 1953.

78. Nilsson, R., "Removal of Metals by Chemical Treatment of Municipal Wastewater", Water Research, 5, p. 51, 1971.

79. Report of the Joint Program of Studies on the Decontamination of Radioactive Waters, ORNL-2557, TID-4500 (14th Ed.) Oak Ridge National Laboratory, Robert A. Taft Sanitary Engineering Center, Feb. 1959.

80. Shen, Y.S., "Study of Arsenic Removal from Drinking Water", JAWWA, p. 543, August 1973.

81. Stone, E.H.F., "Treatment of Non Ferrous Metal Process Wastes of Kynoch Works, Birmingham, England", Proceedings, 22 Annual Industrial Wastes Conference, Purdue University, Part 2, p. 848, 1967.

82. U.S. Public Health Service, "Mercury in Water Supplies", JAWWA, p. 285, 1970.

83. Wesner, G.M., Argo, D., and Culp, G.L., "Heavy Metals Removal in Wastewater Treatment Processes", Orange County Water District Report, 1972.

84. Al-Layla, M.A., and Middlebrooks, E.J., "Algae Removal by Chemical Coagulation", Water & Sewage Works, p. 76, September 1974.

85. AWWA Committee Report, "Coagulation-Filtration Practice as Related to Research", JAWWA, p. 502, August 1974.

86. Bean, E.L., "Study of Physical Factors Affecting Flocculation", Water Works Eng's, p. 33, 1953.

87. Beardsley, J.A., "Use of Polymers in Municipal Water Treatment", JAWWA, p. 85, January 1973.

88. Camp, T.R., "Sedimentation and the Design of Settling Tanks", Transactions of ASCE, 111, p. 895, 1946.

89. Conley, W.R., and Slechta, A.F., "Recent Experiences in Plant Scale Application of the Settling Tube Concept", Presented at the WPCF Conference, Boston, Mass., October 1970.

90. Culp, G.L., Hansen, S.P., and Richardson, G.H., "High Rate Sedimentation in Water Treatment Works", JAWWA, 60, p. 681, 1968.

91. Culp, G.L., Hsiung, K.Y., and Conley, W.R., "Tube Clarification Process, Operating Experiences", Journal, SED, ASCE, SA5, p. 829, October 1969.

92. Eliassen, R., Discussion of (1), Transactions of ASCE, 111, p. 947, 1946.

93. Hanson, S.P., and Culp, G.L., "Applying Shallow Depth Sedimentation Theory", JAWWA, 59, p. 1134, 1967.

94. Hazen, A., "On Sedimentation", Transactions of ASCE, 53, p. 45, 1974.

95. Hudson, H.E., Jr., "Physical Aspects of Flocculation", JAWWA, p. 885, July 1965.

96. Hudson, H.E., Jr., "Density Consdierations in Sedimentation", JAWWA, p. 382, June 1972.

97. Miller, R., "Sedimentation", Water and Wastes Eng'g, p. 40, September 1974.

98. Morrow, J.J., and Rausch, E.G., "Colloid Destabilization with Cationic Polyelectrolytes as Affected by Velocity Gradients", JAWWA, p. 646, November 1974.

99. Parsons, W.A., "Chemical Treatment of Sewage and Industrial Wastes", National Lime Assoc., Washington, D.C., 1965.

100. Robinson, C.N., Jr., "Polyelectrolytes as Primary Coagulants for Potable Water Systems", JAWWA, p. 252, April 1974.

101. Shelton, S.P., and Drewry, W.A., "Tests of Coagulants for the Reduction of Viruses, Turbidity, and COD", JAWWA, p. 627, October 1973.

102. Tolman, S.L., "The Mechanics of Mixing and Flocculation", Public Works, 1962.

103. Winter, R.L., "Selecting Mixers for Treatment Operations", JAWWA, p. 262, April 1974.

104. Thompson, C.G., Singley, J.E., and Blacks, A.P., "Magnesium Carbonate - A Recycled Coagulant", JAWWA, p. 11, January 1972, and p. 93, February 1972.

105. AWWA, "Diatomite Filters for Municipal Use", Task Group Report, JAWWA, p. 157, 1965.

106. Adin, A., and Rebhum, M., "High-Rate Contact Flocculation - Filtration with Cationic Polyelectrolytes", JAWWA, p. 109, February 1974.

107. AWWA Committee Report, "State of the Art of Water Filtration", JAWWA, p. 662, October 1972.

108. Baylis, John R., "Seven Years of High Rate Filtration", JAWWA, p. 585, 1956.

109. Baylis, John R., "Progress in the Design of Rapid Sand Filters, Transactions 2nd Annual Conf. on San Eng., Univ. of Kansas, p. 7, 1952.

110. Bernade, M.A., and Johnson, Barry, "Schistosome Cercariae Removal by Sand Filtration", JAWWA, p. 449, 1971.

111. Boyd, R.H., and Ghosh, M.M., "An Investigation of the Influences of Some Phipiological Variables on Pourous-Media Filtration", JAWWA, p. 94, February 1974.

112. Brown, T.S., Malina, J.F., Jr., Moore, B.D., "Virus Removal by Diatomaceous-Earth Filtration--Part I", JAWWA, p. 98, February 1974.

113. Calise, V.J., and Homer, W.A., "Russian Water Supply and Treatment Practices", J. San. Eng. Div., Proceedings ASCE, p. 1, March 1960.

114. Camp, T.R., "Theory of Water Filtration", Proceedings ASCE, p. 1, 1964.

115. Cleasby, J.L., "Filter Rate Control Without Rate Controllers, JAWWA, p. 181, 1969.

116. Cleasby, J.L., "Approaches to a Filtrability Index for Granular Filters", JAWWA, p. 372, 1969.

117. Cleasby, J.L., Williamson, M.M., and Baumann, R.E., "Effect of Filtration Rate Changes on Quality", JAWWA, p. 869, 1963.

118. Conley, W.R., Jr., and Hsiung, K., "Design and Application of Multimedia Filters", JAWWA, p. 97, 1969.

119. Conley, W.R., Jr., "Integration of the Clarification Process", JAWWA, p. 1333, 1965.

120. Conley, W.R., Jr., and Pitman, R.W., "Innovations in Water Clarification", JAWWA, p. 1319, 1960.

121. Conley, W.R., Jr., "Experiences with Anthracite Sand Filters", JAWWA, p. 1473, 1961.

122. Conley, W.R., "Operators Guide to High-Rate Filtration", JAWWA, p. 203, March 1972.

123. Craft, T.F., "Comparison of Sand and Anthracite for Rapid Filtration", JAWWA, p. 10, 1971.

124. Culbreath, Mark C., "Necessary Modifications for High Rate Filtration", JAWWA, p. 699, 1968.

125. Culp, R.L., "New Water Treatment Methods Serve Richland", Public Works, p. 86, July 1964.

126. Diaper, E.W.J., and Ives, K.J., "Filtration Through Size Graded Media", San. Eng. Div., Proceedings ASCE, p. 89, June 1963.

127. Eunpu, Floyd F., "High Rate Filtration in Fairfax County Virginia", JAWWA, p. 340, 1970.

128. Frankel, R.J., "Series Filtration Using Local Filter Media", JAWWA, p. 124, February 1974.

129. Frissora, F.V., "An Advanced Water Filtration Plant", Water and Sewage Works, p. 365, 1971.

130. Geise, G.D., Pitman, R.W., and Wells, G.W., "The Use of Filter Conditioners in Water Treatment", JAWWA, p. 1303, 1967.

131. Hamann, Carl L. and McKinney, Ross E., "Upflow Filtration Process", JAWWA, p. 1023, 1968.

132. Haney, B.J., and Steimle, S.E., "Potable-Water Supply by Means of Upflow Filtration (l'Eau Claire Process)", JAWWA, p. 117, February 1974.

133. Harmeson, R.H., et al., "Coarse Media Filtration for Artificial Recharge", JAWWA, p. 1396, 1968.

134. Harris, W. Leslie, "High-Rate Filter Efficiency", JAWWA, p. 515, 1970.

135. Hudson, H.E., Jr., "Functional Design of Rapid Sand Filters", Div. ASCE, p. 17, 1963.

136. Hudson, H.E., Jr., "Physical Aspects of Filtration", JAWWA, p. 33, 1969.

137. Hudson, H.E., Jr., "High Quality Water Production and Viral Disease", JAWWA, p. 1265, 1962.

138. Hutchinson, W., and Foley, P.D., "Operational and Experimental Results of Direct Filtration", JAWWA, p. 79, February 1974.

139. Ives, K.J., "Progress in Filtration", JAWWA, p. 1-25, 1964.

140. Jung, H., and Savage, E.S., "Deep-Bed Filtration", JAWWA, p. 73, February 1974.

141. Kirchman, W.B., and Jones, W.H., "High-Rate Filtration", JAWWA, p. 157, March 1972.

142. Kreissl, J.F., Robeck, G.G., and Sommerville, G.A., "Use of Pilot Filters to Predict Optimum Chemical Feeds", JAWWA, p. 299, 1968.

143. Laughlin, J.E., and Duvall, T.E., "Simulataneous Plant Scale Tests of Mixed Media and Rapid Sand Filters", JAWWA, p. 1015, 1968.

144. Minz, D.M., "Modern Theory of Filtration", Special Subject No. 10, International Water Supply Assoc., London, 1966.

145. Mohanka, S.S., "Multilayer Filtration", JAWWA, p. 504, 1969.

146. Moffett, J.W., "The Chemistry of High Rate Water Treatment", JAWWA, p. 1255, 1968.

147. Morey, E.F., "High-Rate Filtration - Media Concepts", Public Works, p. 80, May 1974.

148. Moulton, F., Bedc, C., and Guthrie, J.L., "Mixed-Media Filters Clean 50 MGD Without Clarifiers", Chemical Processing, March 1968.

149. Nelson, O.F., "Capping Sand Filters", JAWWA, p. 539, 1969.

150. Oakley, H.R., and Cripps, T., "British Practice in the Tertiary Treatment of Sewage", JWPCF, p. 36, 1969.

151. O'Conner, J.T., and Baliga, K.Y., "Control of Bacterial Growths in Rapid Land Filters", JSED, ASCE, p. 1377, December 1970.

152. Oeben, R.W., Haines, H.P., and Ives, K.J., "Comparison of Normal and Reverse-Graded Filtration", JAWWA, p. 429, 1968.

153. O'Melia, C.R., and Crapps, D.K., "Some Chemical Aspects of Rapid Sand Filtration", JAWWA, p. 1326, 1964.

154. O'Melia, C.R., and Stumm, Werner, "Theory of Water Filtration", JAWWA, p. 1393, 1967.

155. Pitman, R.W., and Wells, G.W., "Activated Silica as a Filter Conditioner", JAWWA, p. 1667, 1968.

156. Rice, A.H., "High-Rate Filtration", JAWWA, p. 258, April 1974.

157. Rice, A.H., and Conley, W.R., "The Microfloc Process in Water Treatment", Tappi, p. 167A, 1961.

158. Riddick, T.M., "Filter Sand", JAWWA, p. 121, 1940.

159. Robeck, G.G., Clarke, N.A., and Dostal, K.A., "Effectiveness of Water Treatment Processes in Virus Removal", JAWWA, p. 1275, 1962.

160. Robeck, G.G., Dostal, K.A., and Woodward, R.L., "Studies of Modification in Water Filtration", JAWWA, p. 198, 1964.

161. Sedore, J.K., "We Converted to High Rate Filtration", Amer. City, 1968.

162. Segall, B.A., and Okun, D.A., "Effect of Filtration Rate on Filtrate Quality, JAWWA, p. 468, 1966.

163. Seth, A.K. et al., "Nematode Removal by Rapid Sand Filtration", JAWWA, p. 962, 1968.

164. Shea, T.G., Gates, W.E., and Argaman, Y.A., "Experimental Evaluation of Operating Variables in Contact Flocculation", JAWWA, p. 41, 1971.

165. Shull, K.W., "Experiences with Multi-bed Filters", JAWWA, p. 314, 1965.

166. Smit, P., "Upflow Filter", JAWWA, p. 804, 1963.

167. Sprink, S.M., and Monscitz, J.T., "Design and Operation of a 200 MGD Direct-Filtration Facility", JAWWA, p. 127, February 1974.

168. Sweeney, G.E., and Prendville, P.W., "Direct Filtration: An Economic Answer to a City's Water Needs", JAWWA, p. 65, February 1974.

169. Syrotynski, S., "Microscopic Water Quality and Filtration Efficiency", JAWWA, p. 237, 1971.

170. Talley, D.G., Johnson, J.A., and Pilzer, J.E., "Continuous Turbidity Monitoring", JAWWA , p. 184, March 1972.

171. Tredgett, R.G., "Direct-Filtration Studies for Metropolitan Toronto", JAWWA, p. 103, February 1974.

172. Tuepker, J.L. and Buescher, C.A., Jr., "Operation and Maintenance of Rapid Sand and Mixed-Media Filters in a Lime Softening Plant", JAWWA, p. 1377, 1968.

173. Walker, J.D., "High Energy Flocculation and Air-Water Backwashing", JAWWA, p. 321, 1968.

174. Walton, Graham, "Effectiveness of Water Treatment Processes", U.S. Public Health Service, Publication No. 898, 1962.

175. Westerhoff, G.P., "Experience with Higher Filtration Rates", JAWWA, p. 376, 1971.

176. Willis, J.F., "Direct Filtration an Economic Answer to Water Treatment Needs", Public Works, p. 87, November 1972.

177. Woodward, R.L., "Relation of Raw Water Quality to Treatment Plant Design", JAWWA, p. 432, 1969.

178. Yao, K.M., Hubibjun, M.T., and O'Melia, C.R., "Water and Wastes Filtration-Concepts and Application", ES & T, p. 1105, November 1971.

179. AWWA Committee Report, "Viruses in Water", JAWWA, p. 491, October 1969.

180. Baur, F., "Contract Granted for Sodium Hypochlorite Generator", Public Works", p. 76, June 1972.

181. Bendes, R.J., "Ozonation, Next Step to Water Purification", Power, August 1970.

182. Berg, G., "Removal of Viruses from Water and Wastewater", Dept. of Civil Engineering, University of Illinois, 1971.

183. Berg, G., "Virus Transmission by the Water Vehicle III. Removal of Viruses by Water Treatment Procedures", Health Laboratory Science, p. 17, July 1966.

184. Berg, G., Dean, R.B., and Dahling, D.R., "Removal of Poliovirus 1 from Secondary Effluent by Lime Flocculation and Sand Filtration", JAWWA, p. 193, February 1968.

185. Black, A.P., Kinman, R.N.,Thomas, W.C., Jr., Freund, G., and Bird, E.D., "Use of Iodine for Disinfection", JAWWA, p. 140, November 1965.

186. Black, A.P., Thomas, W.C., Jr., Kinman, R.N., Bonner, W.P., Keirn, M.A., Smith, J.J., Jr., and Jabero, A.A., "Iodine for the Disinfection of Water", JAWWA, p. 69, January 1968.

187. Buelow, R.W., and Walton, G., "Bacteriological Quality vs. Residual Chlorine", JAWWA, p. 29, January 1971.

188. Burns, R.W., and Sproul, O.J., "Viricidal Effects of Chlorine in Wastewater", JWPCF, p. 1834, November 1967.

189. Calif. Dept. of Public Health, Bur. of San. Eng'g., "Wastewater Chlorination for Public Health Protection", Proc. 5th Annual San. Eng.'g Symposium, May 1970.

190. Chaudhuri, M., and Engelbrecht, R.S., "Removal of Viruses from Water by Chemical Coagulation and Flocculation", JAWWA, p. 563, September 1970.

191. Clarke, N.A., Berg, G., Kabler, P.W., and Chang, L.L., "Human Enteric Viruses in Water: Source, Survival, and Reveability", International Conference on Water Pollution Research, London, September 1972.

192. Clarke, N.A., and Buelow, R.W., "Disinfection: What It Does", Proceedings, Fifth Annual Sanitary Engineering Symposium, Calif. Dept. of Public Health, May 1970.

193. Clarke, N.A., and Kabler, P.W., "The Inactivation of Purified Coxsackie Virus in Water by Chlorine", American Journal of Hygiene, p. 119, January 1954.

194. "Coliform Organisms as an Index of Water Safety", Committee on Public Health Activities, Journal SED, ASCE, p. 41, November 1961.

195. Collins, H.F., "Chlorination -- How to Use it", Proceedings Fifth Annual Sanitary Engineering Symposium, California Dept. of Public Health, May 1970.

196. Connell, G.F., and Fetch, J.J., "Advances in Handling Gas Chlorine", JWPCF, p. 1505, August 1969.

197. Cookson, J.T., Jr., "Mechanism of Virus Adsorption on Activated Carbon", JAWWA, p. 52, January 1969.

198. Craun, G.F., and McCabe, L.J., "Review of the Causes of Waterborne-Disease Outbreaks", JAWWA, p. 74, January 1973.

199. Fiedler, R.P., "On-Site Caustic Chlorine Generation for Water Disinfection", JAWWA, p. 46, January 1974.

200. Geldreich, E.E., and Clarke, N.A., "The Coliform Test: A Criterion for the Viral Safety of Water", Dept. of Civil Engineering, University of Illinois, 1971.

201. Gomella, Cyril, "Ozone Practices in France", JAWWA, p. 39, 1972.

202. Hann, V.A., "Disinfection of Drinking Water With Ozone",JAWWA, p. 1316, October 1956.

203. Harris, W.C., "Ozone for Water: What's the Story", Water and Wastes Engineering, p. 44, November 1974.

204. Harris, W.C., "Ozone Disinfection", JAWWA, p. 182, March 1972.

205. Just, J. and Szniolis, A., "Germicidal Properties of Silver in Water", JAWWA, p. 492, 1936.

206. Kabler, P.W., Chang, S.L., Clarke, N.A., and Clark, H.F., "Pathogenic Bacteria and Viruses in Water Supplies", 5th Sanitary Engineering Conference, U. of Illinois, January 1963.

207. Karalekas, P.C., Jr., Kuzminski, L.N., and Feng, T.H., "Recent Developments in the Use of Iodine for Water Disinfection", Journal New England Water Works Association, p. 152, June 1970.

208. Kruse, C.W., Olivieri, V.P., and Kawata, K., "The Enhancement of Viral Inactivation by Halogens", Water and Sewage Works, p. 187, June 1971.

209. Laubusch, E.J., "Hypochlorites", Public Works, p. 106, June 1963. Stenquist, R.J., and Kaufman, W.J., "Initial Mixing in Coagulation Processes", EPA Report EPA-R2-72-053, November 1972.

210. Laubusch, E.J., "Chlorine: Its Development, Characteristics and Utility for Disinfection and Oxidation", Proceedings, 3rd University of Illinois Sanitary Engineering Conference, 1961.

211. Liu, O.C., Seraichekas, H.R., Akin, E.W., Brashear, D.A., Katz, E.L., and Hill, W.J., Jr., "Relative Resistance of Twenty Human Enteric Viruses to Free Chlorine in Potomac Water", Dept. of Civil Eng'g, Univ. of Illinois, 1971.

212. Manwaring, J.F., Chaudhuri, M., and Engelbrecht, R.S., "Removal of Viruses by Coagulation and Flocculation", JAWWA, p. 298, May 1971.

213. McDermott, J.H., "Virus and Water Quality: Occurrence and Control - Conference Summary", Dept. of Civil Eng'g., Univ. of Illinois, 1971.

214. McKee, J.E., Brokaw, C.J., and McLaughlin, R.T., "Chemical and Colicidal Effects of Halogens in Sewage", JWPCF, p. 795, August 1960.

215. Melnick, J.L., "Detection of Virus Spread by the Water Route", Proceedings of Conf. on Virus and Water Quality: Occurrence and Control, Dept. of Civil Engineering, Univ. of Illinois, 1971.

216. Michalek, S.A. and Leitz, F.B., "On-site Generation of Hypochlorite", JWPCF, p. 1697, September 1972.

217. Morris, J., "Chlorination and Disinfection-State of the Art", JAWWA, p. 769, December 1971.

218. Oliver, D.O., "Viruses in Water and Wastewater: Effects of Some Treatment Methods", Dept. of Civil Eng'g., Univ. of Illinois, 1971.

219. "Parisian Water Gets Ozone Treatment", Water and Wastes Engineering, p. 83, September 1969.

220. Scarpino, P.V., Berg, G., Chang, S.L., Dahling, D., and Lucas, M., "A Comparative Study of the Inactivation of Viruses in Water by Chlorine", Water Research , p. 959, 1972.

221. Sommerville, R.C., and Rampel, G., "Ozone for Supplementary Water Treatment", JAWWA, p. 377, June 1972.

222. Sproul, O.J., "Virus Inactivation by Water Treatment", JAWWA, p. 31, January 1972.

223. Stringer, R., and Kruse, C.W., "Amoebic Cysticidal Properties of Halogens", Proceedings of the National Specialty Conference on Disinfection, ASCE, New York, NY 1970.

224. Thorup, R.T., Nixon, F.P., Wentworth, D.F., and Sproul, O.J., "Virus Removal by Coagulation with Polyelectrolytes", JAWWA, p. 97, February 1970.

225. Walton, G., "Effectiveness of Water Treatment Processes as Measured by Coliform Reduction", U.S. Public Health Service Pub. No. 898, 1962.

226. "Water Chlorination -- Principles and Practices", American Water Works Association Manual of Water Supply Practices M-20, 1973.

227. White, G.C., "Handbook of Chlorination", Van Nostrand Reinhold Co., New York, 1972.

228. Yao, K.M., "Is Chlorine the Only Answer", Water and Wastes Engineering, p. 30, January 1972.

229. Fernando, C.C., Midkiff, W.S., and O'Conner, G.A., "Calcium Carbonate Ion-Pair as a Limit to Hardness Removal", JAWWA, p. 524, September 1974.

230. Judkins, J.J., Jr., and Wynne, R.H., Jr., "Crystal-Seed Conditioning of Lime-Softening Sludge", JAWWA, p. 306, May 1972.

231. Kunin, R., "Ion Exchange Resins", John Wiley & Sons, New York, 1958.

232. Larson, T.E., "The Ideal Lime-Softened Water", JAWWA, p. 649, May 1951.

233. Lynch, M.A., Jr., Mintz, M.S., "Membrane and Ion Exchange Processes - A Review", JAWWA, p. 711, November 1972.

234. Nordell, E., "Water Treatment for Industrial and Other Uses", Van Nostrand Reinhold Co., New York, 1961.

235. Powell, S., "Water Conditioning for Industry", McGraw Hill Book Co., New York, 1954.

236. Riehl, M.L., "Hoover's Water Supply and Treatment", Nat'l. Lime Assoc., 1962.

237. Wood, F.A., "Selecting a Softening Process", JAWWA, p. 820, December 1972.

238. AWWA, "Water Quality and Treatment", McGraw Hill Book Co., NY, 1971.

239. Haney, P.D., "Theoretical Principles of Aeration", JAWWA, p. 353, April 1954.

240. Camp, T.R., "Gas Transfer To and From Aqueous Solutions", JSED, ASCE, SA4:1701, July 1958.

241. Anderson, D.R., Row, D.D., and Sindelar, G.E., "Iron & Manganese Studies of Nebraska Water Supplies", JAWWA, p. 635, October 1973.

242. Dart, F.J., and Foley, P.D., "Silicote as Fe, Mn, Deposition Preventative in Distribution Systems", JAWWA, p. 244, April 1972.

243. Goswami, S.R., "Iron Removal in Municipal Treatment Plants", Water and Sewage Works, p. 52, October 1973.

244. Griffin, A.E., "Significance and Removal of Manganese in Water Supplies", JAWWA, p. 1326, 1960.

245. Longley, J.M., Englebrecht, R.S., and Margrave, G.E., "Laboratory and Field Studies on the Treatment of Iron Bearing Waters", JAWWA, p. 732, June 1962.

246. O'Connor, J.T., and Benson, B.E., "Iron Removal Using Magnesium Oxide", JSED, ASCE, p. 1, 335, December 1970.

247. Robinson, L.R., Jr., and Dixon, R.I., "Iron and Manganese Precipitation in Low Alkalinity Ground Waters", Water and Sewage Works, November 1968.

248. Anon, "Keep Your Fluoride Flowing", Water & Wastes Eng'g., p. 34, October 1972.

249. AWWA, "Standards for Sodium Fluoride, Sodium Silicofluoride and Fluorilicic Acid", AWWA, January 1971 and June 1971.

250. Bellack, E., "Fluoridation Engineering Manual",U.S. Env. Prot. Agency, 1972.

251. Culp, R.L., and Stoltenberg, H.A., "Fluoride Reduction at LaCrosse, Kansas", JAWWA, p. 423, 1958.

252. Ingram, W.T., "Application of Fluorides to Water", Water & Sewage Works, May 1961.

253. Ingram, W.T., and Moore, G.W., "Fluoridation in the Major Cities of the U.S.", JAWWA, September 1959.

254. Maier, F.J., "Defluoridation of Municipal Water Supplies", JAWWA, p. 879, 1953.

255. Maier, F.J., "Manual of Water Fluoridation Practice", McGraw Hill Book Co., New York.

256. Oskerhowsen, R.W., "Safe Handling of Water Works Chemicals",JAWWA, June 1971.

257. Ruzicka, J.A., and Mrklas, L., "Aluminum in Fluoridated Drinking Water: Analytical and Physiological Problems", JAWWA, p. 53, January 1974.

258. Leferian, S., "Fluoride Handling Safety", JAWWA, p. 604, September 1972.

259. Walker, R.J., and Smith, R.R., "Continuous Analysis and Control of Fluoride", JAWWA, April 1971.

260. Culp, R.L., and Culp, G.L., "Recarbonation", Advanced Wastewater Treatment, Van Nostrand Reinhold Co., New York, p. 69, 1971.

261. Ghosh, M.M., "Chemical Conditioning to Control Water-Quality Failure in Distribution Systems", JAWWA, p. 348, May 1973.

262. Langelier, W.F., "The Analytical Control of Anti-Corrosion Water Treatment", JAWWA, p. 1500, December 1956.

263. Reihl, M.L., "Recarbonation of Lime Softened Water", Hoover's Water Supply & Treatment, Nat'l. Lime Assoc., Wash., D.C., p. 125, 1957.

264. Bruvold, W.H., Ongerth, H.J., and Dillehay, R.F., "Consumer Assessment of Mineral Taste in Domestic Water", JAWWA, p. 575, 1969.

265. Cohen, M.J., Kamphake, L.J., Harris, E.K., and Woodward, R.L., "Taste Threshold Concentrations of Metal in Drinking Water", JAWWA, p. 660, 1960.

266. Hansen, R.E., "Granular Carbon Filters for Taste and Odor Removal", JAWWA, p. 176, March 1972.

267. Monscvitz, J.T. and Aimsworth, L.D., "Treatment for Hydrogen Polysulfide", JAWWA, p. 537, September 1974.

268. Murray, W.B., "Taste and Odor Control with Sulfamic Acid", JAWWA, p. 259, April 1972.

269. Narayan, L.V. & Nunez, W.J., III, "Biological Control: Isolation and Bacterial Oxidation of the Taste and Odor Compound Geosmin", JAWWA, p. 532, September 1974.

270. Popalisky, J.R., and Pogge, F.W., "Detecting & Treating Organic Taste & Odor Compounds in the Missouri River", JAWWA, p. 505, August 1972.

271. Bishop, W.F., and Murphy, M., "Electrodialysis", JAWWA, p. 783, November 1972.

272. Chew, M.C., Mitchell, R.N., and Brevold, W.H., "Public Response to Desalted Sea Water for Domestic Supply", JAWWA, p. 8, January 1974.

273. Edwards, V.H., and Schubert, P.F., "Removal of 2,4-D and Other Persistent Organic Molecules from Water Supplies by Reverse Osmosis", p. 610, JAWWA, October 1974.

274. Faber, H.A., Bresler, S.A., and Walton, G., "Improving Community Water Supplies with Desalting Technology", JAWWA, p. 705, November 1972.

275. Dodson, R.W., AWWA Committee Report, "An Overview of Water Desalting", JAWWA, p. 367, June 1972.

276. Fraser, J.H., Gibson, W.E., "Secondary Refrigerant Desalination, JAWWA, p. 746, November 1972.

277. Halpern, B.M., Olie, J., "1.25 MGD Electrodialysis Desalination Plant in Israel's Desert", JAWWA, p. 735, November 1972.

278. Heckroth, C.W., "Desalination", Water & Wastes Eng'g. p. 20, July 1974.

279. Holzmacker, R.G., "Nitrate Removal from Ground Water Supply", Water & Sewage Works, p. 210, July 1971.

280. Kennedy, J.R., and Chillcott, C.H., "Operating Experiences at Desalting Plants", JAWWA, p. 772, November 1972.

281. Krebs, F.W., Cofer, J.R., and Sieveka, E.H., "Sea-Water Distillation Module", JAWWA, p. 749, November 1972.

282. Miller, E.F., "Desalting as a Source of Water Supply", JAWWA, p. 804, December 1972.

283. Montanari, F.W., and Brennan, C.M., "Water Supply From Estuarial Sources", JAWWA, p. 761, November 1972.

284. Scheffer, S.L., "History of Desalting Operation, Maintenance, and Cost Experience at Buckeye, Arizona", JAWWA, p. 726, November 1972.

285. Strobel, J.J., "Growth of Desalting Technology", JAWWA, p. 701, November 1972.

286. AWWA, Statement on Chloro-Organic Compounds in Drinking Water, November,1974.

287. AWWA, "Standard for Granular Activated Carbon", JAWWA, p. 672, November, 1974.

288. Bellar, T.A., Lichtenberg, J.J., and Kroner, R.C., "The Occurrence of Organohalides in Finished Drinking Waters", EPA National Env. Res. Center, Cincinnati, Ohio, 1974, unpublished.

289. Bellar, T.A., and Lichtenberg, J.J., "The Determination of Volutile Organic Compounds at the UG/l Level in Water by Gas Chromatography", EPA NERC, Cincinnati, Ohio, 1974, unpublished.

290. Buelow, R.W., Corswell, J.K., and Symons, J.M., "An Improved Method for Determining Organics by Activated Carbon Adsorption and Solvent Extraction", JAWWA, p. 57, Jan. 1973, and p. 195, March 1973.

291. Burnham, A.K., et al., "Trace Organics in Water: Their Isolation and Identification", JAWWA, p. 722, November 1973.

292. Cameron, C.D., Hoehn, R.C., and Strimaitis, J.R., "Organic Contaminants in Raw and Finished Water", JAWWA, p. 519, September 1974.

293. Culp, R.F., and Culp, G.L., "Advanced Wastewater Treatment", Van Nostrand Reinhold Co., New York, 1971.

294. Dostal, K.A., Pierson, R.C., Hager, D.G., and Robeck, C.C., "Carbon Bed Design Criteria Study at Nitro, W. Va.", Journal American Water Works Association, 57, p. 663, May 1965.

295. Eichelberger, J.W., and Litchenberg, J.J., "Carbon Adsorption for Recovery of Organic Pesticides", JAWWA, p. 25, 1971.

296. EPA, "Optimization of the Regeneration Procedure for Activated Carbon", WPCRS, 17020 DAO, Supt. of Documents, Wash., D.C. 20402, July 1970.

297. EPA, "Process Manual for Carbon Adsorption", EPA Technology Transfer Section, Second Edition, October 1973.

298. Epstein, S.S., "Environmental Determinants of Human Cancer", Cancer Research, 34, p. 2425, October 1974.

299. Flentje, M.E., and Hager, D.C., "Advances in Taste and Odor Removal with Granular Carbon Filters", Water and Sewage Works, February 1964.

300. Hager, D.C., and Flentje, M.E., "Removal of Organic Contaminants by Granular Carbon Filtration", JAWWA, p. 1440, November 1965.

301. Hager, D.C., and Fulker, R.D., "Adsorption and Filtration with Granular Activated Carbon", Journal of the Society for Water Treatment and Examination, 17, p. 41, 1968.

302. Hansen, R.E., "Granular Carbon Filters for Taste and Odor Removal", JAWWA, p. 176, March 1972.

303. Harris, R.H., "The Implications of Cancer-Causing Substances in Mississippi River Water", Report to New Orleans, Ca. City Council, November 6, 1974.

304. Hassler, J.W., "Activated Carbon", Chemical Publ. Co., NY, 1974.

305. Hyndshaw, A.Y., "The Selection of Granular Versus Powdered Activated Carbon", Water and Wastes Engineering, p. 49, February 1970.

306. Hyndshaw, A.Y., "Activated Carbon to Remove Organic Contaminants from Water", JAWWA, p. 309, May 1972.

307. Jolley, R.L., "Chlorination Effects on Organic Constituents in Effluents from Domestic Sanitary Sewage Treatment Plants", Oak Ridge National Lab., Publ. No. 565, ORNL-TM-4290, October 1973.

308. Klaffke, K., "Granular Carbon System Purifies Water at Del City, Oklahoma", Water and Wastes Engineering, March 1968.

309. Kovach, J.L., "Activated Carbon Dechlorination", Industrial Water Engineering, p. 30, October-November 1971.

310. Manka, J., Reblrum, M., Mandlebaum, A., and Bortinger, A., "Characterization of Organics in Secondary Effluents", Environmental Science and Technology, p. 1, 017, November 1974.

311. Ongerth, H.J., et al., "Public Health Aspects of Organics in Water", JAWWA, p. 495, July 1973.

312. Rook, J.J., "Formation of Haloforms During Chlorination of Natural Waters", Water Treatment and Examination, Vol. 23, Part 2, p. 234, 1974.

313. Saunders, R.A., Griffith, J.R., and Soalfeld, F.E., "Identification of Some Organic Smog Components Based on Rain Water Analysis", Journal of Biomedical Mass Spectrometry, 1, p. 192, 1974.

314. Saunders, R.A., et al., "Identification of Volatile Organic Contaminants in Washington, D.C., Municipal Water", Naval Research Lab., Wash., D.C., 1974, unpublished.

315. Scheinman, M.A., Saunders, R.A., and Soalfeld, F.E., "Organic Contaminants in the District of Columbia Water Supply", Naval Research Lab., Wash., D.C., 1974, to be published in Journal of Biomedical Mass Spectrometry.

316. Semmins, M., and Gregory, J., "Selectivity of Strongly Basic Anion Exchange Resins for Organic Anions", Env. Science & Technology, p. 834, September 1974.

317. U.S. Public Health Service, "Report of the Secretary's Commission on Pesticides and Their Relationship to Environmental Health", Dept. of HEW, U.S. Govt. Printing Office, Washington, D.C., December 1969.

BIBLIOGRAPHY

SECTION IV CHEMICAL APPLICATION

1. Anon., "Keep Your Fluoride Flowing", Water and Wastes Engineering, p. 34, October, 1972.

2. Anon., "Liquid Polymers Prove Out in the Field", Water and Sewage Works, p. 64, October, 1973.

3. AWWA, "Safety Practices for Water Utilities", AWWA Manual of Water Supply Practices M3, 1971.

4. AWWA Standards, AWWA, Denver, Colorado.

5. AWWA, "Water Chlorination Principles and Practices", AWWA Manual of Water Supply Practices M-20, 1973.

6. AWWA, "Water Quality and Treatment", McGraw-Hill Bok Co., New York, 1971.

7. AWWA, "Water Treatment Plant Design", AWWA, Denver, Colorado, 1969.

8. Beardsley, J.A., "Use of Polymers in Municipal Water Treatment", JAWWA, p. 85, January, 1973.

9. Bellack, E., "Fluoridation Engineering Manual", EPA Water Supply Programs Division, Washington, D.C., 1972.

10. Brodeur, T.P., and Bauer, D.A., "Picking the Best Coagulant for the Job", Water and Wastes Engineering, p. 52, May, 1974.

11. "Chlorine Manual", Chlorine Institute, 342 Madison Avenue, New York.

12. Collins, H.F., "Design of Chlorine Contact Tanks for Maximum Kill", Calif. Dept. of Public Health, Berkeley, Calif., April, 1971.

13. Connell, G.F., and Fitch, J.J., "Advances in Handling Gas Chlorine", JWPCF, p. 1505, August, 1969.

14. Dart, F. J., and Foley, P.D., "Silicate as Fe, Mn Deposition Preventative in Distribution Systems", JAWWA, p. 244, April, 1972.

15. EPA, "Field Detection and Damage Assessment Manual for Oil and Hazardous Material Spills", EPA Division of Oil and Hazardous Materials, Washington, D.C., June, 1972.

16. EPA Report, "Coagulant Aids for Water Treatment", JAWWA, p. 735, November, 1973.

17. Harris, W.C., "Ozone for Water: What's the Story?", Water and Waste Engineering, p. 44, November, 1974.

18. Harris, W.C., "Ozone Disinfection", JAWWA, p. 102, March, 1972.

19. Maier, F.J., "Manual of Water Fluoridation Practices", McGraw-Hill Book Co., New York, 1963.

20. Maier, F.J., and Bellack, E., "Fluorpar for Fluoridation", JAWWA, p. 34, January, 1957.

21. Moyer, K.A., "Water Chlorination Methods", Water and Sewage Works, p. 64, September, 1974.

22. Ockershausen, R.W., "Safe Handling of Water Works Chemicals", p. 336, June, 1971.

23. Riehl, M.L., "Water Supply and Treatment", National Lime Assoc., Washington, D.C., 1963.

24. Rosen, H.M., "Ozone Generation and Its Economical Application in Wastewater Treatment", Water and Sewage Works, p. 114, September, 1972.

25. Seferian, S., "Fluoride - Handling Safety", JAWWA, p. 604, September, 1972.

26. White, G.C., "Handbook of Chlorination", Van Nostrand Reinhold Co., New York, 1972.

BIBLIOGRAPHY

SECTION V PUMPING FACILITIES

1. Alexander, R.J., "Telemetry Control of Pumps and Operators", JAWWA, p. 231, April, 1970.
2. Ambrosini, A., "Types of Variable - Speed Pump Controls in Water Service", JAWWA, p. 710, June, 1964.
3. ASME, "Power Test Code for Centrifugal and Rotary Pumps", ASME.
4. Aubrey, M.W., "Description of Continuous Pumping", JAWWA, p. 601, May, 1965.
5. AWWA, "American National Standard for Deep Well Vertical Turbine Pumps - Line Shaft and Submersible Types", AWWA #101 - 71, and Appendix A, Field Testing of Deep Well Turbine Pumps, AWWA, Denver, Colorado, 1971.
6. AWWA, "Ground Water - Manual M21", AWWA, Denver, Colorado, 1973.
7. Babbitt, H.E., and Doland, J.J., "Water Supply Engineering", McGraw-Hill Book Co., New York, 1939.
8. Becker, E.W., "Protecting Pumping Stations Against Nuclear Attack", JAWWA, p. 392, August, 1969.
9. Bennison, E.W., "Ground Water, Its Development, Uses, and Conservation", Edward E. Johnson, Inc., St. Paul, Minn., 1947.
10. Cardillo, P.E., and Eakins, Wayne, "Field Testing of Centrifugal Wastewater Pumps", Public Works, p. 55, December, 1974.
11. Davis, C.V., "Handbook of Applied Hydraulics", McGraw-Hill Book Co., New York, 1952.
12. DeVries, R.N., "Reading Pump Curves", JAWWA, p. 442, June, 1973.
13. Edwards, J.A., "Pumps for Pollution Control", Pollution Engineering, p. 26, November, 1974.
14. Farmer, E., "Alternative Sources of Power for Water Utility Pumping Stations", JAWWA, p. 1297, October, 1958.
15. Gallagher, D.L., "Installation, Operation, and Maintenance of Water Pumps", JAWWA, p. 441, March, 1958.
16. Inglasbe, W.E., "Pump Surges in Closed Piping Systems", JAWWA, p. 668, November, 1974.

17. Kristal and Annett, "Pumps", McGraw-Hill Book Co., New York.

18. Lescovich, J.E., "Locating and Sizing Air-Release Valves", JAWWA, p. 457, July, 1972.

19. Martin, J.L., et al, "Analysis of a Transmission System Containing Booster Pumps, JAWWA, p. 238, April, 1972.

20. Texas, WW and Sewerage Short School, "Manual for Water Works Operators", Texas State Department Health, Austin, Texas, 1951.

21. Thomas, H.E., "The Conservation of Ground Water", McGraw-Hill Book Co., New York, 1951.

22. Weaver, D.L., "Surge Control", JAWWA, p. 462, July, 1972.

23. Winn, W.P., "Throttling Valves: Testing and Selection", JAWWA, p. 163, March, 1972.

BIBLIOGRAPHY

SECTION VI STORAGE

1. AWWA, "AWWA Standard for Welded Steel Elevated Tanks, Standpipes, and Reservoirs for Water Storage", AWWA D100-73, AWWA, Denver, Colorado, 1973.

2. AWWA, "AWWA Standard for Inspecting and Repairing Steel Water Tanks, Standpipes, Reservoirs, and Elevated Tanks, for Water Storage", AWWA D101-53, AWWA, Denver, Colorado, 1953.

3. AWWA, "AWWA Standard for Painting and Repainting Steel Tanks, Standpipes, Reservoirs, and Elevated Tanks for Water Storage", AWWA, D102-64, AWWA, Denver, Colorado, 1964.

4. AWWA, "Water Distribution Training Course", Manual No. M8, AWWA, Denver, Colorado, 1962.

5. Brock, D.A., "Determination of Optimum Storage in Distribution System Design", JAWWA, p. 1,027, August, 1963.

6. Chin, A.G., "Covering Open Distribution Reservoirs", JAWWA, p. 763, December, 1971

7. Davis, C.V., "Handbook of Applied Hydraulics", McGraw-Hill Book Co., New York, 1952.

8. Dykmans, M.J., "Prestressed Concrete Tanks - Design Factors and Economy", JAWWA, p. 591, May, 1965.

9. Elkins, H.B., "Lead Content of Water From Tanks Painted With Red Lead", JAWWA, p. 570, May, 1959.

10. EPA, "Manual for Evaluating Public Drinking Water Supplies", Supt. of Documents, Washington, D.C. 1971.

11. Emigh, F.A., "Protection of Open Reservoirs Against Birds", JAWWA, p. 1353, November, 1962.

12. Fair and Geyer, "Water Supply and Wastewater Disposal", John Wiley and Sons, New York, 1959.

13. Farmer, Ed, "Storage and Distribution for Peak Loads", JAWWA, p. 135, February, 1962.

14. Fee, J.R., "Planning Distribution Storage in Nonhilly Areas", p. 714, June, 1960.

15. Freese, S.W., "Peak Demand Storage", JAWWA, p. 263, March, 1957.

16. Great Lakes - Upper Mississippi River Board of Sanitary Engineers, "Recommended Standards for Water Works", N.Y. State Health Education Services, Albany, N.Y., 1972.

17. Haskew, G.M., Jr., "Storage Tank Location", JAWWA, p. 296, March, 1963.

18. Harem, F.E., "Maintenance and Repair of Concrete Reservoirs", JAWWA, p. 1,160, September, 1964.

19. Hartman, B.J., "Types and Uses of Water Storage", JAWWA, p. 395, March, 1959.

20. Jackson, J.E., "Better Performance From Paints for Steel Water Tanks", JAWWA, p. 577, September, 1970.

21. Jackson, J.O., "Stronger Steels for Tanks", JAWWA, p. 1,390, November, 1965.

22. Jones, F.E., and Greenberg, A.E., "Coliform Bacteria in Redwood Storage Tanks", JAWWA, p. 1,489, November, 1964.

23. McCaughan, F.A., "Pneumatic Application of Cement - Mortar Tank Coatings", JAWWA, p. 1,145, September, 1965.

24. McPherson, M.B., and Wood, G., "Operating Options for Pumped Equalizing Storage", JAWWA, p. 869, July, 1965.

25. Neumayer, C.A., Jr., "Determining Reserve and Equalizing Storages", JAWWA, p. 1499, November, 1957.

26. Patterson, A.B., "Design of Underground Storage Reservoirs", JAWWA, p. 1,499, November, 1957.

27. Prazer, S.J., "Reservoir Renovation: Butyl-Rubber Lining and Floating Cover", JAWWA, p. 151, February, 1973.

28. Shelton, F.G., "Water-Tank Maintenance and Repair Practices", JAWWA, p. 472, August, 1974.

29. Smith, M.C., "Advantages of Ground Level Distribution Storage", JAWWA, p. 1,559, December, 1959.

30. Stearns, D.E., "Advantages of Additional Storage Facilities for Improving Distribution Systems", JAWWA, p. 661, May, 1958.

31. Texas Water Works and Sewerage Short School, "Manual for Water Works Operators", Texas State Dept. of Health, Austin, Texas, 1951.

32. Wade, J.A., Jr., "Design Guidelines for Distribution Systems as Developed and Used by an Investor-Owned Utility", JAWWA, p. 346, June, 1974.

33. Walters, C.G., "Prestressed Concrete Tanks - Maintenance and Repair", JAWWA, p. 596, May, 1965.

34. Woodside, R.D., "Prestressed Concrete Storage Tanks: Design and Construction", JAWWA, p. 389, May, 1972.

35. Wormald, L.W., "Water-Storage-Tank Failure Due to Freezing and Pressurization", JAWWA, p. 173, March, 1972.

BIBLIOGRAPHY

SECTION VII DISTRIBUTION SYSTEMS

General

1. AWWA Committee Report, "Replacement of Water Distribution Mains", JAWWA, p. 417, September, 1969.

2. AWWA Committee Report, "Water-Distribution Research and Applied Development Needs", JAWWA, p. 385, June, 1974, and p. 407, September, 1974.

3. "AWWA Manual M-8, Water Distribution Training Course", AWWA, Denver, Colorado, 1962.

4. AWWA Panel Discussion, "Computer Applications in Distribution System Operations", JAWWA, p. 134, February, 1973.

5. AWWA Panel Discussion, "Telemetering", JAWWA, p. 491, August, 1971.

6. AWWA Panel Discussion, "Locating Leaks in Mains and Services", JAWWA, p. 403, July, 1970.

7. AWWA Policy Statement, "Grounding of Electrical Circuits on Water Pipe", JAWWA, p. 321, July, 1970.

8. Anon, "What Can Be Done about Leakage", Water and Wastes Engineering, p. 22, August, 1972.

9. Baeckmann, W.G., "Cathodic Protection of Underground Pipelines With Special Reference to Urban Areas", JAWWA, p. 466, August, 1974.

10. Bailey, E.W., "Cathodic Protection for Coated Steel Pipelines", JAWWA, p. 85, February, 1971.

11. Becker, A.E., Jr., et al, "Computer Techniques for Water - Distribution Analysis", JAWWA, p. 410, July, 1972.

12. Bottles, D.G., "Use of Plastic Pipe", JAWWA, p. 55, January, 1970.

13. Buus, P., "Installing Backflow Preventers", JAWWA, p. 314, May, 1970.

14. Campbell, F.C., "Distribution System Leakage Survey", JAWWA, p. 400, July, 1970.

15. Carl, K.J., et al, "Guidelines for Determining Fire-Flow Requirements", JAWWA, p. 335, May, 1973.

16. Carl, K.J., "Municipal Fire Protection Surveys and Gradings", JAWWA, p. 123, March, 1969.

17. Carlson, C.E.C., "The Denver System of Water Works Controls", JAWWA, p. 513, August, 1971.

18. Carlton, E.E., "Electrical Grounding and Resulting Corrosion", JAWWA, p. 471, August, 1974.

19. Chenwith, H.E., and Crawford, C., "Pipe Network Analysis", JAWWA, p. 55, January, 1974.

20. Clark, C.M., "Expansive - Soil Effects on Buried Pipe", JAWWA, p. 424, July, 1971.

21. Cote, D.R., and Goodman, A.S., "Cost of Providing Water for Fire Protection", JAWWA, p. 407, July, 1970.

22. Cruse, H., and Pomeroy, R.D., "Corrosion of Copper Pipes", JAWWA, p. 479, August, 1974.

23. Dahl, R., "Cleaning and Lining Small-Diameter Pipe", JAWWA, p. 483, August, 1974.

24. Davis, C.V., "Handbook of Hydraulics", McGraw-Hill Book Co., N.Y., 1952.

25. Dressendorfer, P.V., and Halff, A.H., "Large Water Mains: Experiences and Practice of Three Large Users", JAWWA, p. 435, July, 1972.

26. Ebner, T.L., "Automatic Meter Reading", JAWWA, p. 112, February, 1973.

27. EPA, "Manual for Evaluating Public Drinking Water Supplies", Supt. of Documents, Washington, D.C., 1971.

28. Fair, G.M., Geyer, J.G., and Morris, J.C., "Water Supply and Wastewater Disposal", John Wiley and Sons, N.Y., 1959.

29. Farish, C.A., "Plastic Pipe and Water Quality", JAWWA, p. 480, September, 1969.

30. Francis, J.L., "Designing Residential Water Services", JAWWA, p. 85, February, 1970.

31. Freeston, R.C., "Controls for a Small Water Utility", JAWWA, p. 523, August, 1971.

32. Frenz, C.M., "Automated System Control", JAWWA, p. 508, August, 1971.

33. Frye, S.C., "Epoxy Lining for Steel Water Pipe", JAWWA, p. 498, August, 1974.

34. Garrett, J.W., "An Application of Computers to Water-System Control: Santa Clara Valley Water District", JAWWA, p. 338, June, 1974.

35. Ghosh, M.M/, "Chemical Conditioning to Control Water-Quality Failure in Distribution Systems", JAWWA, p. 348, May, 1973.

36. Gilman, H.D., et al, "Replication Modeling for Water-Distribution Control", JAWWA, p. 255, April, 1973.

37. Goebel, E., "Cleaning and Cement-Mortar Lining of Water Mains", JAWWA, p. 365, June, 1970.

38. Hann, R.W. Jr., "System Simulation for Analysis and Design", JAWWA, p. 279, May, 1970.

39. Herman, J.A., "Engineering Considerations in Piping", JAWWA, p. 416, July, 1971.

40. Holler, A.C., "Corrosion of Water Pipes", JAWWA, p. 456, August, 1974.

41. Hucks, R.T. Jr., "Designing PVC Pipe for Water Distribution Systems", JAWWA, p. 443, July, 1972.

42. Ingalsbe, W.E., "Pump Surges in Closed Piping Systems", JAWWA, p. 668, November, 1974.

43. Janson, L.E., and Valimaa, P., "Some Investigations Concerning UPVC Water and Sewer Pipes and Fittings", JAWWA, p. 360, June, 1964.

44. Kay, G.H., "Asbestos in Drinking Water", JAWWA, p. 513, September, 1974.

45. Kennedy, H. Jr., "External Loads and Foundations for Pipes", JAWWA, p. 189, March, 1971.

46. Kiser, K.B., "Distribution System Records", JAWWA, p. 418, July, 1972.

47. Kocol, R.J., "Pressure Testing the Distribution System in Milwaukee", JAWWA, p. 430, July, 1972.

48. Laatsch, E., and Kortens, P., "Meter Maintenance", JAWWA, p. 197, March, 1972.

49. Lee, R.L., "Controls for a Medium-Sized Water Utility", JAWWA, p. 526, August, 1971.

50. LiBrizzi, G.C., "Distribution System Design vs. Inner-City Redevelopment", JAWWA, p. 343, June, 1974.

51. Lincoln, D.A., "Denver's Procedures and Practices for Corrosion Control", JAWWA, p. 91, February, 1970.

52. Lischer, V.C., "AWWA Pipe Standards in Pipeline Engineering", JAWWA, p. 455, September, 1969.

53. Manganaro, C.A., "Harnessed Joints for Water Pipe", JAWWA, p. 347, July, 1969.

54. McClanahan, M.A., and Mancy, K.H., "Comparison of Corrosion-Rate Measurements on Fresh and Previously Pollarized Samples", JAWWA, p. 461, August, 1974.

55. McClelland, N.I., and Mancy, K.H., "Water Quality Monitoring in Distribution Systems", JAWWA, p. 795, December, 1972.

56. McCullough, J.A., and Bailey, E.W. Jr., "Eliminating Air From the Colorado Springs Distribution System", JAWWA, p. 94, February, 1970.

57. Mogren, F.E., "A Maintenance Program for Valves and Hydrants", JAWWA, p. 507, July, 1973.

58. Monie, W.D., and Clark, C.M., "Loads on Underground Pipe Due to Frost Penetration", JAWWA, p. 353, June, 1974.

59. Morris, R.E. Jr., "PVC Pipe", JAWWA, p. 578, September, 1972.

60. Muldowney, J.J., "Design Problems in Distribution Networks", JAWWA, p. 363, June, 1970.

61. Mullen, E.D., and Ritter, J.A., "Potable-Water Corrosion Control", p. 473, August, 1974.

62. Neel, R.C., "Computer Applications in Distribution", JAWWA, p. 485, August, 1971.

63. N.Y. State Dept. of Health Bulletin No. 22, "Water Supply Control", Div. of Env. Health Services, Albany, N.Y., 1962.

64. Olson, H.L., "Asbestos in Potable - Water Supplies", JAWWA, p. 515, September, 1974.

65. Pearson, H.E., and Singer, P.R., "Water-Quality Considerations in Water Distribution From Two Sources", JAWWA, p. 600, October, 1974.

66. Pentecost, F.C., "Design Guidelines for Distribution Systems", JAWWA, p. 332, June, 1974.

67. Popalisky, J.R., "Experiences With Butterfly Valves", JAWWA, p. 349, June, 1974.

68. Starr, J.D., "How Chicago Manages Its Distribution System", JAWWA, p. 328, June, 1974.

69. Selander, C.E., and Simonds, R.A., "Field Testing of Plastic and Plastic-Clad Pipes", JAWWA, p. 421, July, 1971.

70. Stead, I.W., "Remote Control and Supervision of Distribution Systems", JAWWA, p. 351, June, 1974.

71. Stearn, H.M., "Cleaning Water Mains With Foam Plugs", JAWWA, p. 414, July, 1971.

72. Taranto, A.G., "Stabilizing an Agressive Water to Stop Consumer Complaints", Public Works, p. 70, December, 1974.

73. Tart, J.S., "Value of Telemetering and Recording", JAWWA, p. 123, February, 1973.

74. Texas Water Works and Sewerage Short School, "Manual for Water Works Operators", Texas State Dept. of Health, Austin, Texas, 1951.

75. Timblin, L.O. Jr., "Progress Report on the Evaluation of RPM Pipe", JAWWA, p. 449, July, 1972.

76. Tinkey, A.M., "Unitized Blocking - A New Concept", JAWWA, p. 274, May, 1970.

77. Trivers, R.E., et al, "Water-Distribution - System Corrosion Control", JAWWA, p. 453, August, 1974.

78. Van Dyke, R.P., "Computerized Operation of Distribution Systems", JAWWA, p. 234, April, 1970.

79. Victoreen, H.T., "Control of Water Quality in Transmission and Distribution Mains", JAWWA, p. 369, June, 1974.

80. Wade, J.A. Jr., "Design Guidelines for Distribution Systems as Developed and Used by an Investor-Owned Utility", JAWWA, p. 346, June, 1974.

81. Wagner, E.F., "Autogenous Healing of Cracks in Cement-Mortar Linings for Gray Iron and Ductile-Iron Water Pipe", JAWWA, p. 358, June, 1974.

82. Wagner, J. Jr., "Corrosion-Control Law and Its Effect on Water-Distribution Systems", JAWWA, p. 458, August, 1974.

83. Watkins, R.K., and Smith, A.B., "Deflection of Buried Pipes", JAWWA, p. 588, September, 1973.

84. Weaver, D.L., "Surge Control", JAWWA, p. 462, July, 1972.

85. Wilging, R.C., "PVC Pipe for Water-Distribution Systems", JAWWA, p. 497, August, 1972.

86. Wool, J.M., and Yale, R.A., "Water Utilities' Use of Plastic Pipe", JAWWA, p. 123, February, 1971.

Materials and Installation

87. "American National Standard for Thickness Design of Cast-Iron Pipe", ANSI A21.1 - 1967, AWWA, Denver, Colorado, 1972.

88. "American National Standard for Cement-Mortar Lining for Cast-Iron and Ductile-Iron Pipe and Fittings for Water", ANSI A21.4, 1971, AWWA, Denver, Colorado, 1971.

89. "American National Standard for Cast-Iron Pipe Centrifugally Cast in Metal Molds for Water or Other Liquids", ANSI A21.6, 1971, AWWA, Denver, Colorado, 1970.

90. "American National Standard for Cast-Iron Pipe Centrifugally Cast in Sand-Lined Molds, for Water or Other Liquids", ANSI A21.8, 1970, AWWA, Denver, Colorado, 1970.

91. "American National Standard for Gray-Iron Ductile-Iron Fittings, 2 inches through 48 inches for Water and Other Liquids", ANSI A21.10, 1971, AWWA, Denver, Colorado, 1971.

92. "American National Standard for Rubber-Gasket Joints for Cast-Iron and Ductile-Iron Pressure Pipe and Fittings", ANSI A21.11, 1972, AWWA, Denver, Colorado, 1972.

93. "American National Standard for 2 inch and 2 1/2 inch Cast-Iron Pipe, Centrifugally Cast, for Water and Other Liquids", ANSI A21.12, 1971, AWWA, Denver, Colorado, 1971.

94. "American National Standard for Thickness Design of Ductile-Iron Pipe", ANSI A21.50, 1971, AWWA, Denver, Colorado, 1971.

95. "American National Standard for Ductile-Iron Pipe, Centrifugally Cast in Metal Molds or Sand-Lined Molds, for Water or Other Liquids", ANSI 21.51, 1971, AWWA, Denver, Colorado, 1971.

96. "American National Standard for Polyethylene Encasement for Gray and Ductile Cast-Iron Piping for Water and Other Liquids", ANSI A21.5, 1972, AWWA, Denver, Colorado, 1972.

97. "AWWA Manual M-6, Water Meters, Selection, Installation, Testing and Maintenance", AWWA, Denver, Colorado, 1973.

98. "AWWA Manual M-9, Installation of Concrete Pipe", AWWA, Denver, Colorado, 1961.

99. "AWWA Manual M-11, Steel Pipe Design and Installation", AWWA, Denver, Colorado, 1964.

100. "AWWA Manual M-17, Installation, Operation, and Maintenance of Fire Hydrants", AWWA, Denver, Colorado, 1970.

101. "AWWA Standard for Fabricated Electrically Welded Steel Water Pipe", AWWA C201-66, AWWA, Denver, Colorado, 1966.

102. "AWWA Standard for Mill-Type Steel Water Pipe, AWWA C202-64", AWWA, Denver, Colorado, 1964.

103. "AWWA Standard for Coal - Tar Enamel Protective Coatings for Steel Water Pipe, AWWA C203-66", AWWA, Denver, Colorado, 1966.

104. "AWWA Standard for Cement-Mortar Protective Lining and Coating for Steel Water Pipe - 4 inch and Larger - Shop Applied, AWWA C205-71", AWWA, Denver, Colorado, 1971.

105. "AWWA Standard for Field Welding of Steel Water Pipe Joints, AWWA 206-62", AWWA, Denver, Colorado, 1962.

106. "AWWA Standard for Steel Pipe Flanges, AWWA C207-55", AWWA, Denver, Colorado, 1955.

107. "AWWA Standard for Dimensions for Steel Water Pipe Fittings, AWWA C208-59", AWWA, Denver, Colorado, 1959.

108. "AWWA Standard for Reinforced - Concrete Water Pipe - Steel Cylinder Type, Not Prestressed, AWWA C300-64", AWWA, Denver, Colorado, 1964.

109. "AWWA Standard for Prestressed Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids, AWWA C301-72", AWWA, Denver, Colorado, 1972.

110. "AWWA Standard for Reinforced - Concrete Water Pipe, Noncylinder Type, Not Prestressed, AWWA C302-64", AWWA, Denver, Colorado, 1964.

111. "AWWA Standard for Reinforced Concrete Water Pipe - Steel Cylinder Type, Pretensioned, AWWA C303-70", AWWA, Denver, Colorado, 1970.

112. "AWWA Standard for Asbestos - Cement Pressure Pipe for Water and Other Liquids, AWWA C400-72", AWWA, Denver, Colorado, 1972.

113. "AWWA Standard for Installation of Asbestos - Cement Water Pipe, AWWA, C603-65", AWWA, Denver, Colorado, 1965

114. "AWWA Standard for Installation of Cast-Iron Water Mains, AWWA C600-64", AWWA, Denver, Colorado, 1973.

115. AWWA Panel Discussion, "Field Installation of Pipe", JAWWA, p. 786, December, 1973.

116. "AWWA Standard for Cement - Mortar Lining of Water Pipelines In Place, AWWA C602-67", AWWA, Denver, Colorado, 1967.

117. "AWWA Standard for Disinfecting Water Mains, AWWA C601-68", AWWA, Denver, Colorado, 1968.

118. "AWWA Standard for Hypochlorites - AWWA B300-64", AWWA, Denver, Colorado, 1964.

119. "AWWA Standard for Liquid Chlorine - AWWA B301-59", AWWA, Denver, Colorado, 1959.

120. "AWWA Standard for Caustic Soda, AWWA B501-64", AWWA, Denver, Colorado, 1964.

121. "AWWA Standard for Trisodium Phosphate, AWWA B500-66", AWWA, Denver, Colorado, 1966.

122. "AWWA Standard for Sodium Hexametaphosphate, AWWA B502-67", 1967.

123. "AWWA Standard for Gate Valves - 3 inch Through 48 inch - For Water and Other Liquids, AWWA C500-71", AWWA, Denver, Colorado, 1971.

124. "AWWA Standard for Sluice Gates, AWWA C501-67", AWWA, Denver, Colorado, 1967.

125. "AWWA Standard for Fire Hydrants for Ordinary Water Works Service, AWWA C502-64", AWWA, Denver, Colorado, 1964.

126. "AWWA Standard for Wet-Barrel Fire Hydrants for Ordinary Water Works Service, AWWA C503-70", AWWA, Denver, Colorado, 1970.

127. "AWWA Standard for Rubber - Seated Butterfly Valves, AWWA C504-70", AWWA, Denver, Colorado, 1970.

128. "AWWA Standard for Ball-Valves, Shaft - or Trunion-Mounted - 6 inch Through 48 inch - for Water Pressures up to 300 psi, AWWA C507-73", AWWA, Denver, Colorado, 1973.

129. "AWWA Standard for Cold Water Meters - Displacement Type, AWWA C700-71", AWWA, Denver, Colorado, 1971.

130. "AWWA Standard for Cold-Water Meters - Turbine Type for Customer Service, AWWA C701-70", AWWA, Denver, Colorado, 1970.

131. "AWWA Standard for Cold-Water Meters - Compound Type, AWWA C702-70", AWWA, Denver, Colorado, 1970.

132. "AWWA Standard for Cold-Water Meters - Fire Service Type, AWWA C703-70", AWWA, Denver, Colorado, 1970.

133. "AWWA Standard for Cold-Water Meters - Propellor Type for Main Line Applications, AWWA C704-70", AWWA, Denver, Colorado, 1970.

134. "AWWA Standard for Direct-Reading Remote Registration Systems for Cold-Water Meters, AWWA C706-72", AWWA, Denver, Colorado, 1972.

135. "AWWA Standard for Threads for Underground Service Line Fittings With Appendix on Collected Standards for Service Line Materials, AWWA C800-66", AWWA, Denver, Colorado, 1966.

136. Winslow, J.B., "AWWA Inches Toward PVC Pipe Standard", American City, p. 102, September, 1974.

Cross-Connection Control

137. "American National Standard for Air Gaps in Plumbing Systems, A112.12-1973", ANSI and ASME, N.Y., 1973.

138. AWWA Committee Report, "Use of Backflow Preventers for Cross-Connection Control", JAWWA, p. 1589, December, 1958.

139. "AWWA Manual M-14, Recommended Practice for Backflow Prevention and Cross-Connection Control", AWWA, Denver, Colorado, 1966.

140. "AWWA Standard for Backflow Prevention Devices - Reduced Pressure Principle and Double Check Valve Types, AWWA C506-69", AWWA, Denver, Colorado, 1969.

141. Angele, G.J. Sr., "Cross-Connections and Backflow Prevention", AWWA, Denver, Colorado, 1974.

142. Angele, G.J., "Hospital Water Supplies and Cross-Connection Control", Water and Sewage Works, p. 338, October, 1971.

143. Anon, "Coping With Cross-Connection Control", Water and Wastes Engineering, p. 22, October, 1972.

144. Anon, "How to Prevent Industrial Cross-Connection Dangers", Water Works Engineering, February, 1962

145. Browning, G.E., and Mankin, J.O., "Gastroenteritis Epidemic Owing to Sewage Contamination of Public Water Supply", JAWWA, p. 1465, November, 1966.

146. Campbell, E. H., "Legal Aspects of Cross-Connection Inspections", JAWWA, p. 409, August, 1969.

147. "Cross-Connection Complications", The Capital's Health, D.C. Dept. of Public Health, Washington, D.C., December, 1953.

148. Dawson, F.M., and Kalinske, A.A., "Report on Cross-Connections and Backsiphonage Research", Tech. Bulletin No. 1, National Assoc. of Plbg., Htg., Cooling Contractors, Washington, D.C.

149. Dillon, D.M., "Backflow in Water Lines", Sanitation and Bldg. Maintenance, p. 18, July, 1958.

150. EPA, "Cross-Connection Control Manual", Supt. of Documents, Washington, D.C., 1974.

151. Gifford, O.L., "Plumbing in Care Institutions", Air Cond., Htg., and Ventilating, p. 65, May, 1962.

152. Guss, L.A., "A Guide to Hospital Plumbing", Air Cond. Htg., and Ventilating, p. 71, October, 1961.

153. "Manual of Cross-Connection Control - Recommended Practice", Foundation for Cross-Connection Control Research, Univ. of Southern Calif., Los Angeles, Calif., 1969.

154. McCall, R.G., "Implementing Public Water Supply Regulations", JAWWA, p. 399, July, 1971.

155. Moore, R.E. Jr., "Legal Aspects of Cross-Connections, Inter-Connection, and Back-Flow Protection", JAWWA, p. 495, March, 1941.

156. Panel Discussion, "Coping With Cross-Connection Control", Water and Wastes Engineering, p. 22, October, 1972.

157. Reinecke, E., "Handbook of Cross-Connection Control", FEBCO, Fresno, California, 1964.

158. Ross, E.C., "How We Sold Backflow Protection", American City, p. 148, September, 1969.

159. Springer, E.K., and Reynolds, K.C., "Definitions and Specifications of Double Check Valve Assemblies and Reduced Pressure Principle Backflow Prevention Devices", Univ. of So. California, School of Engineering, Report 48-101, January, 1959.

160. Stacha, J.H., et al, "Cross-Connection Control in the City of Dallas", JAWWA, p. 688, November, 1970.

161. Taylor, F.B., "The Holy Cross Episode", JAWWA, p. 230, April, 1972.

162. Taylor, F.B., and Skodje, M.T., "Cross-Connections, A Hazard in All Buildings", Modern San. and Building Maintenance, August, 1962.

163. U.S.P.H.S., "A Revision of The National Plumbing Code, ASA-A40.8-1955, Report of the PHS Technical Committee on Plumbing Standards", U.S.P.H.S., Washington, D.C., September, 1962.

164. Van Meter, R.O., "Backflow Prevention Hardware", Water and Wastes Engineering, September and October, 1970.

165. Van Meter, R.O., "Implementation of an Effective Cross-Connection Control Program", S. Carolina Public Health Department, Columbia, S. Carolina, January, 1970.

166. West, W.E., "Auxiliary Water Supplies and Cross-Connections", JAWWA, p. 401, August, 1969.

BIBLIOGRAPHY

SECTION VIII OPERATION AND MAINTENANCE

1. Adams, D.S., "Emergency Actions and Disaster Reactions: An Analysis of the Anchorage Public Works Dept. in the 1964 Earthquake", Office of Civil Defense, Office of the Secy. of the Army, Wash., D.C., 1969.

2. Adrian, G.W., et al., "Water Quality After A Disaster", JAWWA, p. 481, Aug. 1972.

3. AWWA, "Installation, Operation, and Maintenance of Fire Hydrants", AWWA M-17 Fire Hydrant Manual, AWWA, Denver, Colorado, 1970.

4. AWWA, "Emergency Planning for Water Utility Management", AWWA Manual M19, AWWA, Denver, Colorado, 1973.

5. AWWA, "Water Utility Management", AWWA Manual M5, AWWA, Denver, Colorado, 1959.

6. AWWA, "Backflow Prevention and Cross-Connection Control", AWWA Manual M14, AWWA, Denver, Colorado, 1966.

7. AWWA Panel Discussion, "Design and Operation of Chlorination Stations Under Normal and Emergency Conditions", JAWWA, p. 869, 1954.

8. AWWA, "Basic Water Treatment Operator's Manual", AWWA Manual M18, AWWA, Denver, Colorado, 1971.

9. AWWA, "Water Distribution Training Course", AWWA Manual No. M8, AWWA, Denver, Colorado, 1962.

10. AWWA Research Foundation, "Report on Water Quality Management", Report for Office of Water Resources Research, U.S. Dept. of Interior, 1973.

11. AWWA, "Water Meters-Selection, Installation, Testing, and Maintenance", AWWA Manual M6, AWWA, Denver, Colorado, 1973.

12. AWWA Committee Report, "Replacement of Water Distribution Mains", JAWWA, p. 417, September, 1969.

13. AWWA, "Water Quality and Treatment", McGraw-Hill Book Co., New York, 1971.

14. AWWA Panel Discussion, "Long-Term Financing and Debt Administration", JAWWA, p. 354, June 1972.

15. Anon., "Instrumentation Improves Water Treatment Plant Operation", Water & Sewage Works, p. 96, June 1974.

16. Anon., "Earthquake Resistance of Rock Fill Dams", Proc. ASCE, Vol. 82, No. SM2, paper No. 941, 1956.

17. Anon., "The California Water Project and Earthquake Engineering", Public Works, p. 65, 1968.

18. Anon., "Effects of Earthquakes on Water Distribution Systems", New Eng. WWA Journal, p. 14, 1942.

19. Anon., "Major Quake Fails to Break Montana Earth Dam", Eng. News Rec., p. 28, 1959.

20. Anon., "Minimum Potable Water Supply Requirements in Civil Defense Emergencies", JAWWA, p. 984, 1959.

21. Arceneaux, W., "Operation and Maintenance of Wells", JAWWA, p. 199, March, 1974.

22. Barron, J.L., "Hurricane Experiences in Nassau County", JAWWA, p. 512, 1945.

23. Becker, R.J., "Maintaining Water-Treatment Equipment", JAWWA, p. 267, April, 1972.

24. Bell, C.G. Jr., et al., "Passage of Nuclear Detonation Debris Through Water Treatment Plants", JAWWA, p. 974, 1954.

25. Berger, B.B., Stevenson, A.H., "Feasibility of Biological Warfare Against Public Water Supplies", JAWWA, p. 101, 1955.

26. Billings, C.H., "The Operation of Water Treatment Plants", Public Works, Ridgewood, N.J.

27. Bingley, W.M., "Responsibility for Plant Operations", JAWWA, p. 132, March, 1972.

28. Brush, W.W., "Minimizing Service Interruptions Due to Transmission Line Failures", JAWWA, p. 627, 1949.

29. Cadman, R.M., "Interruptions in Electrical Supply Along New Jersey Shore During 1944 Hurricane", JAWWA, p. 516, 1945.

30. Calif. Sec. AWWA Earthquake Task Force Committee Report, "Contending with Earthquake Disaster", JAWWA, p. 22, January, 1973.

31. Carlson, C.E.C., "The Denver System of Water Works Controls", JAWWA, p. 513, August, 1971.

32. Caskey, C.C., "The Four Functions of Management", JAWWA, p. 361, June, 1972.

33. Conley, W.R., "Operator's Guide to High-Rate Filtration", JAWWA, p. 203, March, 1972.

34. Cookingham, L.P., "Meeting Flood Problems", JAWWA, p. 811, 1952.

35. Craft, T.F., "Planning for Water Quality Emergencies", JAWWA, p. 181, March, 1970.

36. Dahl, R., "Cleaning and Lining Small-Diameter Pipe", JAWWA, p. 483, August, 1974.

37. Deem, R.E., "The Maintenance Record System: A Managerial Aid", JAWWA, p. 447, August, 1974.

38. Dolson, F.E., "General Principles for the Control of Water Main Breaks", JAWWA, p. 1285, 1958.

39. EPA, "Field Detection and Damage Assessment for Oil and Hazardous Material Spills", EPA Div. of Oil & Hazardous Materials, Wash., D.C., 1972.

40. EPA, "Cross-Connection Control Manual", EPA Water Supply Division, Wash., D.C., 1974.

41. Erickson, C.R., "Water Utility Planning for Nuclear Attack", JAWWA, p. 1237, October, 1963.

42. Fair and Geyer, "Water Supply and Wastewater Disposal", John Wiley & Sons, New York, 1959.

43. Ferguson, G.E., "Combating Water Pollution From Large Oil Spills", JAWWA, p. 678, December, 1969.

44. Fisher, L.M., et al., "Meeting Major Emergencies in Water Supply", JAWWA, p. 1141, 1948.

45. Gallup Poll, "Water Quality and Public Opinion", JAWWA, p. 513, August, 1973.

46. Gilman, C.S., and Meyers, V.A., "Hurricane Winds for Design Along The New England Coast", Trans. ASCE, p. 127, Vol. IV, 1962.

47. Harnett, J.S., "Preventative Maintenance", JAWWA, p. 398, August, 1969.

48. Henn, E.L., "Instrument Operation and Maintenance", JAWWA, p. 280, April, 1973.

49. Highly, E.A., "Financing Water Works Improvements", JAWWA, p. 321, June,1971.

50. Hudson, H.E. Jr., "Evaluation of Plant Operating and Jar Test Data", JAWWA, p. 368, May, 1973.

51. Hurst, W.D., "Winnepeg's Flood Emergency Organization", JAWWA, p. 1095, 1950.

52. Kenmir, R.C., "Periodic Inspection of Tanks and Reservoirs", JAWWA, p. 145, March, 1969.

53. Kincaid, R.G., "Value and Use of System Records in Long-Range Planning", p. 277, February, 1960.

54. Kiser, K.B., "Distribution System Records", JAWWA, p. 418, July, 1972.

55. Knauer, V.H., "The Silent-Consumer Issue", JAWWA, p. 570, October, 1974.

56. Larkin, D.G., "Readiness for Earthquake", JAWWA, p. 405, August, 1969.

57. Lacy, W.J., "Methods of Radioactivity Removal", JAWWA, 1249, 1963.

58. Metzler, D.F., et al., "Interruptions to Water Service by the Kansas Flood of 1951", JAWWA, p. 78, 1952.

59. Minors, C.R., "Effective Public Relations for Public Utilities", JAWWA, p. 585, October, 1974.

60. Mogren, T.D., "A Maintenance Program for Valves and Hydrants", JAWWA, p. 507, July, 1973.

61. Morris, R.E., Jr., "Preventative Maintenance Program at Dallas", JAWWA, p. 579, May, 1964.

62. Musgrave, J.W., "Better Customer Service Through On-Line Computers", JAWWA, p. 169, March, 1973.

63. Nelson, L.M., "Well Operations", JAWWA, p. 436, July, 1970.

64. Norris, D.P., "Techniques for Formalization of Maintenance Problems", JAWWA, p. 935, August, 1962.

65. N. Dakota State Dept. of Health, "Maintenance of Sodium Fluoride Saturator Installations", JAWWA, p. 609, September, 1973.

66. N.Y. State Dept. of Health, "Manual of Instruction for Water Treatment Plant Operators", N.Y. Health Educ. Services, Albany, N.Y.

67. N.Y. State Dept. of Health, "Water Supply Control", Bulletin No. 22, Health Educ. Services, Albany, N.Y., 1962.

68. Ozan, T.M., "Controls for Operations Management", JAWWA, p. 75, February, 1972.

69. Parrish, J.S., "Value of Reports and Budgets in Management", JAWWA, p. 178, February, 1959.

70. Pawlik, C.L., et al., "Texas Coast Hurricane Flood Protection Studies", Jour. Hydraulic Div., ASCE, HY6, p. 147, 1967.

71. Roller, J., et al., "Water-System Operation", JAWWA, p. 222, March, 1973.

72. Schleinger, E.J., 'Pretreatment Settling Basin Is Cleaned By Dredging", Public Works, p. 46, December, 1974.

73. Shelton, F.G., "Water-Tank Maintenance and Repair Practices", JAWWA, p. 472, August, 1974.

74. S. Carolina State Bd. of Health, "Water Works Systems, Maintenance Standards and Policies", S. Carolina SBH, Columbia, S.C., September, 1969.

75. Stearn, H.M., "Cleaning Water Mains With Foam Plugs", JAWWA, p. 414, July, 1971.

76. Taranto, A.G., "Stabilizing An Agressive Water to Stop Consumer Complaints", Public Works, p. 70, December, 1974.

77. Teller, J.P., "Disinfection of a Distribution System After Disaster", JAWWA, p. 1403, 1961.

78. Texas Water Works Short School, "Manual for Water Works Operators", Texas State Dept. of Health, Austin, Texas, 1951.

79. Thurber, M.D., "Computerized Water Treatment Plant Records", Water & Sewage Works, p. 374, November, 1971.

80. Van Dyke, R.P., 'Computerized Operation of Distribution Systems", JAWWA, p. 234, April, 1970.

81. Veatch, N.T., "The Kansas Flood of 1951", JAWWA, p. 765, 1952.

82. Virginia, "Waterworks Regulations", Bureau of San. Engineering, Dept. of Health, Richmond, Va., 1974.

83. Wade, J.A., Jr., "Organization of a Master Disaster Plan", JAWWA, p. 163, 1959.

84. Wedeman, J.D., "Preventative Maintenance for Water Works", JAWWA, p. 281, March, 1956.

85. EPA, "Federal Guidelines for Operation and Maintenance of Wastewater Treatment Facilities", 1974.

BIBLIOGRAPHY

SECTION IX SURVEILLANCE

1. Alley, E.R., and Malaney, G.W., "Simple Method Gives Salmonellae Density", Water and Sewage Works, p. 81, September, 1974.

2. APHA, "Standard Methods for the Examination of Water and Wastewater", Current Edition, APHA, New York.

3. ASCE, AWWA, CSSE, "Water Treatment Plant Design", AWWA, Denver, Colorado, 1969.

4. AWWA Committee Report, "Organic Contaminants in Water", JAWWA, p. 682, November, 1971.

5. AWWA, "Water Quality and Treatment", McGraw-Hill Book Co., New York, 1971.

6. AWWA, "Manual M18, Basic Water Treatment Operator's Manual", AWWA, Denver, Colorado, 1971.

7. AWWA, "Proceedings, Water Technology Conference, Cincinnati, Ohio", AWWA, Denver, Colorado, December 1973.

8. AWWA, "Manual M20, Water Chlorination Principles and Practices", AWWA, Denver, Colorado, 1973.

9. AWWA, "AWWA Manual M12, Simplified Procedures for Water Examination", AWWA, Denver, Colorado, 1964.

10. AWWA Research Foundation Committee Report, "A Study of the Problem of Asbestos in Water", AWWA, Denver, Colorado, September, 1974.

11. AWWA Research Foundation, "Public Water Supply Treatment Technology", AWWA, Denver, Colorado, 1973.

12. Bauer, R., et al, "A Simple Test for Estimating Free Chlorine", JAWWA, p. 787, November, 1972.

13. Bellack, E., "Methods and Materials for Fluoride Analysis", JAWWA, p. 62, January, 1972.

14. Bellar, T.A., and Lichtenberg, J.J., "Determining Volatile Organics at Microgram-per-Liter Levels by Gas Chromatography", JAWWA, p. 739, December, 1974.

15. Bellar, T.A., et al, "The Occurrence of Organohalides in Chlorinated Water", JAWWA, p. 703, December, 1974.

16. Black, A.P., and Smith A.L., "Determination of the Mobility of

Collodial Particles by Microelectrophoresis", JAWWA, p. 926, 1962.

17. Buelow, R.W., et al, "An Improved Method for Determining Organics by Activated Carbon Adsorption and Solvent Extraction", JAWWA, p. 195, March, 1973.

18. Burnham, A.K., et al, "Trace Organics in Water: Their Isolation and Identification", JAWWA, p. 722, November, 1973.

19. Conley, W.R., and Evans, R.H., "Coagulation Control", JAWWA, p. 165, 1968.

20. Caldwell, J.S., et al, "Evaluation of a Low-Cost Arsenic and Selenium Determination at Microgram-per-Liter Levels", JAWWA, p. 731, November, 1973.

21. Castorina, A.R., "Water Sampling and Laboratory Service ", JAWWA, p. 806, December, 1973.

22. Clarke, F.E., "Quest for Quality Control in Water Testing", JAWWA, p. 59, January, 1971.

23. Cox, C.R., "Laboratory Control of Water Purification", Case-Sheppard-Mann Publ. Corp., New York, 1946.

24. Culp and Culp, "New Concepts in Water Purification", Van Nostrand Reinhold Co., New York, 1974.

25. DeMichele, E., et al, "The Need for an Indicator Virus in Water Quality Testing", Water & Sewage Works, p. 39, April, 1974.

26. EPA, "Manual for Evaluating Public Drinking Water Supplies", EPA Water Supply Division, Washington, D.C., 1971.

27. EPA, "Drinking Water Standards", Prepared by the EPA Advisory Committee on the Revision and Application of the Drinking Water Standards as recommended to the Administrator, EPA, September 20,1973.

28. Epstein, J., "Properties of GB (nerve gas) in Water", JAWWA, p. 31, January, 1974.

29. Frazier, R.E., "Pulse Polarography", JAWWA, p. 39, June, 1972.

30. Gerdes, W.F., "A New Instrument -- The Streaming Current Detector", unpublished.

31. Ginsburg, W., et al, "Filter-Fluorescent Antibody Technique for Rapid Screening of Indicator Organisms", JAWWA, p. 499, August, 1972.

32. Greenberg, A.E., and O'Connor, J.T., "Mercury in Water: An Evaluation of Laboratories and Methodology", JAWWA, p. 548, August, 1973.

33. Griffith, J.D., and Williams, R.G., "Application of Jar-Test Analysis at Phoenix, Arizona", JAWWA, p. 825, December, 1972.

34. Guter, K.J., et al, "Evaluation of Existing Field Kits for Determining Free Chlorine Residuals in Aqueous Solutions", JAWWA, p. 38, January, 1974.

35. Harris, R.H., "Control of Filter Aids in High Rate Filters Using Turbidity Monitoring", presented at the New York section AWWA meeting, October, 1970.

36. Hudson, H.E. Jr., "Evaluation of Plant Operating and Jar-Test Data", JAWWA, p. 368, May, 1973.

37. Hurley, J.T., "Pesticide Analysis in Water", JAWWA, p. 27, January, 1974.

38. Jolley, R.L., "Chlorination Effects on Organic Constituents in Effluents from Domestic Sanitary Sewage Treatment Plants", Publ. No. 565, Oak Ridge Natl. Lab., Oak Ridge, Tenn., October, 1973.

39. Kawamura, S., and Tanaka, Y., "Applying Colloid Titration Techniques to Coagulant Dosage Control", Water & Sewage Works, p. 348, 1966.

40. Kawamura, S., Sanna, G.P. Jr., & Shumate, K.S., "Application of Colloid Titration Technique to Flocculation Control", JAWWA, p. 1003, 1967.

41. Kay, G.H., "Asbestos in Drinking Water", JAWWA, p. 513, September, 1974.

42. Kloster, M.B., "The Determination of Tannin and Lignin", JAWWA, p. 44, January, 1974.

43. Manka, J., et al, "Characterization of Organics in Secondary Effluents", Env. Science & Technology, p. 1017, November, 1974.

44. McFarren, E.F., "New, Simplified Method of Metal Analysis" JAWWA, p. 28, January, 1972.

45. Polk, J.L., "Award-Winning Water Treatment Plant Features Automation", Public Works, p. 74, November, 1972.

46. Popalisky, J.R., and Pogge, F.W., "Detecting and Treating Organic Taste-and-Odor Compounds in the Missouri River", JAWWA, p. 505, August, 1972.

47. Riddick, T.M., "Zeta Potential and Its Application to Difficult Waters", JAWWA, p. 1007, August, 1961.

48. Riehl, M.L., "Hoover's Water Supply and Treatment", Natl. Lime Assoc., Washington, D.C., 1957.

49. Rook, J.J., "Formation of Haloforms During Chlorination of Natural Waters", Water Treatment & Examination, p. 234, 1974.

50. Rossum, J.R., "An Inexpensive Precision Conductance Meter", JAWWA, p. 387, June, 1971.

51. Ruzika, J.A., and Mrklas, L., "Aluminum in Fluoridated Drinking Water: Analytical and Physiological Problems", JAWWA, p. 53, January, 1974.

52. Sawyer and McCarty, "Chemistry for Sanitary Engineers", McGraw-Hill Book Co., New York, 1969.

53. Shull, K.E., "Filtrability Techniques for Improving Water Clarification", JAWWA, p. 1164, 1967.

54. Suffett, I.H., and Segall, S., "Detecting Taste & Odor in Drinking Water", JAWWA, p. 605, September, 1971.

55. TeKippe, R.J., and Ham, R.K., "Coagulation Testing, A Comparison of Techniques", JAWWA, p. 594, Part 1; p. 620, Part 2, 1970.

56. U.S. Army Corps of Engineers, "Water Supply - Laboratory Furniture, Apparatus, and Supplies for Water Filtration Plants", Engineering Manual for Water Dept. Construction, Part VII, Appendix B, February, 1946.

57. U.S.P.H.S., "Drinking Water Standards", U.S. Dept. of Health, Educ., and Welfare, Washington, D.C., 1962.

58. U.S.P.H.S., "Evaluation of Water Laboratories", U.S. Dept. of Health, Education, and Welfare, Washington, D.C., 1966.

59. Virginia Dept. of Health, "Waterworks Regulations", Bureau of San. Eng'g., Va. Department of Health, Richmond, Va., 1974.

60. White, G.C., "Handbook of Chlorination", Van Nostrand Reinhold Co., New York, 1972.

61. Willey, B.F., et al, "Atomic Adsorption Spectrophotometry Simplifies Heavy-Metals Analysis", JAWWA, p. 303, May, 1972.

62. Williams, R.L., "Microelectrophoretic Studies of Coagulation With Aluminum Sulfate", JAWWA, p. 801, 1965.

BIBLIOGRAPHY

SECTION X PERSONNEL

1. ABC, AWWA, WPCF Joint Report, "Survey of Operator Certification Programs", JAWWA, p. 831, December, 1972.

2. AWWA, "Water Quality and Treatment", McGraw Hill Book Co., New York, 1971.

3. AWWA, "Water Distribution Training Course", AWWA Manual No. M8, AWWA, Denver, Colorado, 1962.

4. AWWA Committee Report, "Employee Benefits by Water Utilities", JAWWA, p. 169, March, 1971.

5. AWWA, "Water Utility Employee Benefits, 1969", AWWA, Denver, Colorado, 1970.

6. AWWA, "Water Utility Salaries and Wages, 1968".

7. AWWA, "Water Utility Management", AWWA Manual No. M5, AWWA, Denver, Colorado, 1959.

8. AWWA, "Tailgate Safety Lectures", AWWA Manual No. M16, AWWA, December, 1967.

9. AWWA, "Basic Water Treatment Operator's Manual", AWWA Manual No. M18, AWWA, Denver, Colorado, 1971.

10. AWWA, "Safety Practices for Water Utilities", AWWA Manual No. M3, AWWA, Denver, Colorado, 1971.

11. Austin, J.H., "Training-How to do It", JAWWA, p. 431, July, 1970.

12. Babcock, R.H., "Recruiting - A Proposal for Action", JAWWA, p. 421, July, 1973.

13. Becker, H.W., "Safety Beyond the Law", JAWWA, p. 461, July, 1973.

14. Becker, H.W., "AWWA's Safety Programs", JAWWA, p. 445, July, 1973.

15. Billings, C.H., "The Operation of Water Treatment Plants", Public Works, Ridgewood, N.J.

16. Binney, M.C., "Hidden Costs Finance Effective Safety Programs", JAWWA, p. 448, July, 1973.

17. Binney, M.C., and Regandanz, B.E., "Proper Strategies for Upgrading Employee Performance", JAWWA, p. 50, January, 1973.

18. Bourque, J., and Trewin, G.R., "Results of BOAT Training in Ontario", JAWWA, p. 414, July, 1974.

19. Caskey, C.C., "The Four Functions of Management", JAWWA, p. 361, 1972.

20. Cole, G.G.W., "Training Employees for Improved Customer Relations", JAWWA, p. 267, June, 1969.

21. Coleman, J.L., Jr., and Greene, W.L., "Recruiting Professionals is a Dynamic Environment", JAWWA, p. 765, December, 1970.

22. Costello, C.V., "Management Training Short Course", JAWWA, p. 423, July, 1970.

23. Counts, C.A., "Training Water-Treatment Plant Operators: The Problem and a Solution", JAWWA, p. 428, July, 1974.

24. Dyer, G.H., "Manpower: The Important Element in Providing Quality Water Service", JAWWA, p. 434, July, 1974.

25. Dyer, G.H., and Becker, E.W., "Recruiting and Holding Good Employees: Employee Grievance Procedures", JAWWA, p. 465, August, 1970.

26. Eclof, W.K., and Swope, H.G., "Elementary Mathematics for Wastewater Treatment Plant Operators", Water and Sewage Works, Reference No., 1967.

27. EPA, "A Four-Year Wastewater Technology Cirriculum", EPA Training Grants Branch, Washington, D.C., July, 1974.

28. EPA, "Estimating Staffing Needs for Municipal Wastewater Treatment Facilities", EPA Office of Water Program Operations, Washington, D.C., March, 1973.

29. EPA, "Manpower Planning for Wastewater Treatment Plants", prepared for Office of Water Programs, EPA, by Olympus Research Corp.

30. Herrick, J.S., "Public-Service-Executive Motivation: Water Utilities", JAWWA, p. 482, July, 1973.

31. Herzik, G.R., Jr., "Training and Recruitment of Youth for Water Utilities", JAWWA, p. 400, July, 1974.

32. Hill, W.R., "Operator Training in Ohio", JAWWA, p. 418, July, 1974.

33. Horabin, I.S., "Alogrithms. Improving Human Performance: A Research Quarterly", National Society for Programmed Instruction, p. 28, March, 1972.

34. Hudson, H.E., Jr., and Rodriquez, F., "Water Utility Personnel Statistics", JAWWA, p. 485, August, 1970.

35. Hudson, H.E., Jr., "Training Sub-Professional Water System Personnel", JAWWA, p. 120, January, 1968.

36. Hudson, H.E., "Management and Training", JAWWA, p. 391, July, 1974.

37. Husted, H.G., "Meeting Modern Safety Standards", JAWWA, p. 543, July, 1973.

38. Illinois, "Water Supply Operator Certification Law", State of Illinois EPA, September, 1973.

39. Jacobs, H.C., "Accident Prevention and OSHA", JAWWA, p. 468, July, 1973.

40. Jeffrey, E.A., "Water Supply Training and Manpower Needs", J. New Eng. WWA, p. 2, June, 1972.

41. Jobes, H.D., "Water Utilities Operator Training: A Worthy Investment", Water and Sewage Works, p. 58, April, 1974.

42. Maryland, "Regulations Governing the Certification of Supts. of Water Works and Wastewater Works", Maryland State Department of Health and Mental Hygiene, Baltimore, Maryland, 1970.

43. McAdams, K.G., "Job Evaluation and Classification", JAWWA, p. 405, July, 1974.

44. Meers, J.E., and Straczek, W.D., "Basic Calculations for Wastewater Treatment Plant Operators", Water & Sewage Works, Reference Number, 1967.

45. Mees, Q.M., "The AWWA Accreditation Program", JAWWA, p. 396, July, 1974.

46. N.Y. State Department of Health, "Manual of Instruction for Water Treatment Plant Operators", N.Y. Health Education Services, Albany, New York, 1968.

47. Ohio, "Water Supply Works and Wastewater Works Personnel", Ohio EPA, September, 1966.

48. O'Meara, R.G., "A Sound Safety Program", JAWWA, p. 572, September, 1972.

49. Oregon State University, "Basic Manual for Water Works Operators", Oregon State Board of Health, Portland, Oregon.

50. Osborne, T.Z., "Evaluating Employee Performance", JAWWA, p. 398, July, 1974.

51. Redekopp, A.B., and Woloschuk, B.Z., "The Importance of Effective Training Programs", JAWWA, p. 410, July, 1974.

52. Remus, G., "Building Reliability of Plant, People, and Service", JAWWA, p. 38, January, 1970.

53. Robinson, W.L., "The Problem of Employee Turnover: Can Training Help?", JAWWA, p. 425, July, 1974.

54. Schwing, C.M., "Training and Recruiting of Water-Utility Personnel", JAWWA, p. 423, July, 1974.

55. Seidel, H.F., "Employee Motivation and Recognition", JAWWA, p. 412, July, 1974.

56. Sims, D.A., "Employee-Benefit Trends", JAWWA, p. 207, April, 1972.

57. Texas W.W. and Sewerage Short School, "Manual for Water Works Operators", Texas Department of Health, Austin, Texas, 1951.

58. Van Dyke, R.P., "Management's New Look in the Manpower Revolution", JAWWA, p. 402, July, 1974.

59. Warrington, S.L., "Training and Certification of Water and Wastewater Personnel", Public Works, p. 68, October, 1974.

60. Watts, P., "Gearing the Junior College to Help Operators", JAWWA, p. 75, February, 1970.

61. WPCF, "The Ways and Means of Operator Advancement", Deeds and Data, WPCF, November, 1974.

62. EPA, "A Classification System for Water and Wastewater Facilities and Personnel", by the Association of Boards of Certification, June, 1974.

APPENDIX A

GLOSSARY OF TERMS

ABS - Customary abbreviation for alkyl benzene sulfonate.

absorption - The taking up of one substance into the body of another.

access tube - A vertical steel riser pipe on an elevated water tank containing access ladder and/or overflow pipe.

activated carbon - Carbon particles usually obtained by carbonization of cellulosic material in the absence of air and possessing a high adsorptive capacity.

activated silica - A negatively charged colloidal particle formed by the reaction of a dilute sodium silicate solution with a dilute solution of an acidic material or other activant. Used primarily as a coagulant aid.

adsorption - (1) The adherence of a gas, liquid, or dissolved material on the surface of a solid. (2) A change in concentration of gas or solute at the interface of a two-phase system. Should not be confused with absorption.

adsorption isotherm - A measurement of the adsorptive capacity of an adsorbent as a function of the concentration, or pressure, of the adsorbing material at a given temperature. It is defined as the constant temperature relationship between amount adsorbed per unit weight of adsorbent and the equilibrium concentration, or partial pressure.

aeration - (1) The bringing about of intimate contact between air and a liquid by one or more of the following methods: (a) spraying the liquid in the air, (b) bubbling air through the liquid, (c) agitating the liquid to promote surface absorption of air. (2) The supplying of air to confined spaces under nappes, downstream from gates in conduits, etc, to relieve low pressures and to replenish air entrained and removed from such confined spaces by flowing water. (3) Relief of the effects of cavitation by admitting air to the section affected.

aerobic - Requiring, or not destroyed by, the presence of free elemental oxygen.

afterprecipitation - The precipitation of colloidal calcium carbonate on the sand grains of a filter and/or in the pipes of the distribution system after treatment of the water with lime.

agglomeration - The coalescence of dispersed suspended matter into larger flocs or particles which settle rapidly.

agitator - Mechanical apparatus for mixing and/or aerating; a device for creating turbulence.

air and vacuum valve - An air valve which permits entrance of air into an empty pipe to counteract a vacuum and escape of accumulated air. Also called vacuum valve.

air binding - (1) A condition occurring in the soil as a result of the increase in the pressure of the air trapped in the interstices thereof, which causes a decrease in the rate of infiltration of water into the soil. (2) The clogging of a filter, pipe, or pump due to the presence of entrained air.

air-gap separation - The unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or outlet supplying water to a tank, plumbing fixture, or other device, and the flood-level rim of the receptacle.

air-lift - A device for raising liquid by injecting air in and near the bottom of a riser pipe submerged in the liquid to be raised.

air relief valve - An air valve placed at the summit of a pipeline to release the air automatically and prevent the pipeline from becoming air-bound with a resultant increase of pressure.

algae - Primitive plants, one-or many-celled, usually aquatic, and capable of elaborating their foodstuffs by photosynthesis.

algal bloom - Large masses of microscopic and macroscopic plant life, such as green algae, occurring in bodies of water.

algicide - Any substance or chemical applied to kill or control algal growths.

alkalinity - The capacity of water to neutralize acids, a property imparted by the water's content of carbonates, bicarbonates, hydroxides, and occasionally borates, silicates, and phosphates. It is expressed in milligrams per liter of equivalent calcium carbonate.

altitude-control valve - A valve that automatically shuts off the flow when the water level in a water storage tank reaches a predetermined elevation and opens when the pressure on the system side is less than on the tank side.

alum - A common name, in the water and wastewater treatment field, for commercial-grade aluminum sulfate.

amperometric titration - The electrometric detection of the equivalent point in a titration by observation of the change in diffusion current at a suitable applied voltage as a function of the volume of titrating solution.

anaerobic- Requiring, or not destroyed by, the absence of air or free (elemental) oxygen.

analysis - (1) The record of an examination of water or wastewater. (2) The resolution of complex problems, bodies, or liquids into their elements.

annual flood - The maximum 24-hr. average rate of flow occurring in a stream during any period of 12 consecutive months. It is the usual practice to consider the 12-month period as extending from October 1 of one year to September 30 of the following year.

anthracite - Hard coal, crushed and screened to proper grain size for use as water filter medium.

applied water - Filter influent water.

appurtences - Machinery, appliances, or auxiliary structures attached to a main structure to enable it to function, but not considered an integral part of it.

aquifer - A porous, water-bearing geologic formation. Generally restricted to materials capable of yielding an appreciable supply of water.

artesian - Pertaining to groundwater, or things connected with groundwater (e.g., a well or underground basin), where the water is under pressure and will rise to a higher elevation if afforded an opportunity to do so.

artificial recharge - Replenishment of the groundwater supply by means of spreading basins, recharge wells, irrigation, or induced infiltration of surface water.

asbestos-cement pipe - A pipe made of a mixture of asbestos fiber and Portland cement combined under pressure.

average daily flow - The total quantity of liquid tributary to a point divided by the number of days of flow measurement.

backflow - (1) A flow condition, induced by a differential in pressure, that causes the flow of water or other liquid into the distribution pipes of a potable water supply from any source or sources other than its intended source. (2) The backing up of water through a conduit or channel in the direction opposite to normal flow.

backflow connection - In plumbing, any arrangement whereby backflow can occur. Also called interconnection, cross connection. See backflow.

backflow preventer - A device for a water supply pipe to prevent the backflow of water into the water supply system from the connections on its outlet end.

backflow-prevention device - Any effective device, method, or construction used to prevent backflow into a potable water system.

backsiphonage - A form of backflow caused by a negative or subatmospheric pressure within a water system. See backflow.

backwashing - The operation of cleaning a filter by reversing the flow of liquid through it and washing out matter previously captured in it. Filters would include true filters such as sand and diatomaceous-earth types but not other treatment units such as trickling filters.

bacterial examination - The examination of water and wastewater to determine the presence, number, and identification of bacteria. Also called bacterial analysis.

bacteriological aftergrowth - Growth of bacteria in a waterpipe, reservoir, or stream after treatment.

baffles - Deflector vanes, guides, grids, gratings, or similar devices constructed or placed in flowing water, wastewater, or slurry systems to check or effect a more uniform distribution of velocities; absorb energy; divert, guide, or agitate the liquids; and check eddies.

base exchange - The exchange of positive ions, on a prepared medium, to replace an undesired ion, such as calcium or magnesium, with a more desirable one, such as hydrogen or sodium. The reaction is reversible if the concentrations are changed.

bicarbonate alkalinity - Alkalinity caused by bicarbonate ions.

biodegradation (biodegradability) - The destruction of mineralization of either natural or synthetic organic materials by the microorganisms populating soils, natural bodies of water, or wastewater treatment systems.

blowoff - A controlled outlet on a pipeline, tank, or conduit that is used to discharge water or accumulations of material carried by a fluid.

BOD - (1) Abbreviation for biochemical oxygen demand. The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions. (2) A standard test used in assessing wastewater strength.

booster pump - A pump installed on a pipeline to raise the pressure of the water on the discharge side of the pipe.

bored well - A well that is excavated by means of an auger (hand or power) as distinguished from one that is dug, drilled, or driven.

breakpoint chlorination - Addition of chlorine to water or wastewater until the chlorine demand has been satisfied and further additions result in a residual that is directly proportional to the amount added beyond the breakpoint.

bridging - Arching of grains of fine or coarse filter media.

butterfly valve - A valve wherein the disk, as it opens or closes, rotates about a spindle supported by the frame of the valve. The valve is opened at a stem. At full opening, the disk is in a position parallel to the axis of the conduit.

caisson - A watertight chamber used in construction work under water.

capacity - (1) The quantity that can be contained exactly, or the rate of flow that can be carried exactly. (2) The load for which a machine, apparatus, station, or system is rated.

carbonate alkalinity - Alkalinity caused by carbonate ions.

carbonate hardness - Hardness caused by the presence of carbonates and bicarbonates of calcium and magnesium in water. Such hardness may be removed to the limit of solubility by boiling the water. When the hardness is numerically greater than the sum of the carbonate alkalinity and the bicarbonate alkalinity, that amount of hardness which is equivalent to the total alkalinity is called carbonate hardness.

carbonation - The diffusion of carbon dioxide gas through a liquid to render the liquid stable with respect to precipitation of dissolution of alkaline constituents.

carbon chloroform extraction (CCE) - A method of assessing organic pollutants in water. It consists of adsorbing organic material on activated carbon, then extracting it with chloroform.

cascade aerator - An aerating device built in the form of steps or of an inclined plane on which are placed staggered projections arranged to break up the water and bring it into contact with air.

cast iron pipe - A pipe made from pig iron cast in a revolving, water-cooled mold, or in a stationary, cylindrical sand mold with a round, central core.

catchment area - (1) The intake area of an aquifer, and all areas that contribute surface water to the intake area. (2) In tropical island zones, a hard-surfaced area on which rain is collected and then conducted to a reservoir. (3) The area tributary to a lake, stream, sewer, or drain. Also called catchment basin.

cathodic protection - An electrical system for prevention of rust, corrosion, and pitting of steel and iron surfaces in contact with water, whereby a low-voltage current is made to flow through a liquid or a soil in contact with the metal in such a manner that the external electromotive force renders the metal structure cathodic and concentrates corrosion on auxiliary anodic parts used for the purpose.

cation - The ion in an electrolyte which carries the positive charge and which migrates toward the cathode under the influence of a potential difference.

caustic alkalinity - The alkalinity caused by hydroxyl ions.

cavitation - (1) The action resulting from forcing a flowing stream to change direction in which reduced internal pressure causes dissolved gases to expand, creating negative pressure. Cavitation frequently causes pitting of the hydraulic structure affected. (2) The formation of a cavity between the downstream surface of a moving body, for example, the blade of a propellor, and a liquid normally in contact with it.

CCE - Carbon chloroform extraction.

cement-lined pipe - A cast-iron, wrought-iron, or steel pipe, the interior of which has been lined with a smooth, dense, thin layer of cement mortar to reduce corrosion and to increase the smoothness of the interior of the pipe.

centrifugal pump - A pump consisting of an impeller fixed on a rotating shaft and enclosed in a casing, and having an inlet and a discharge connection. The rotating impeller creates pressure in the liquid by the velocity derived from centrifugal force.

certified pump - Pump unit performance as attested to by manufacturer based on factory tests by the manufacturer or by an independent inspector.

check valve - A valve provided with a disk hinged on one edge so that it opens in the direction of normal flow and closes with reversal of flow. An approved check valve is of substantial construction and suitable materials, is positive in closing, and permits no leakage in a direction opposite to the normal flow.

chelating agent - A chemical or complex which causes an ion, usually, a metal, to be joined in the same molecule by both ordinary and coordinate valence forces. Such linkage result in the formation of one or more heterocyclic rings in which the metal atom is part of the ring. Commercially available chelating agents may be used to remove traces of metal ions in industrial and biological processes.

chemical dose - The application of a specific quantity of chemical to a specific quantity of fluid for a specific purpose.

chemical feeder - A device for dispensing a chemical at a predetermined rate for the treatment of water or wastewater. Change in rate of feed may be affected manually or automatically by flow-rate changes. Feeders are designed for solids, liquids, or gases.

chemical oxygen demand (COD) - A measure of the oxygen-consuming capacity of inorganic and organic matter present in water or wastewater. It is expressed as the amount of oxygen consumed from a chemical oxidant in a specific test. It does not differentiate between stable and unstable organic matter and thus does not necessarily correlate with biochemical oxygen demand. Also known as OC and DOC, oxygen consumed and dichromate oxygen consumed, respectively.

chloramines - Compounds of organic or inorganic nitrogen and chlorine.

chlorination - The application of chlorine to water or wastewater, generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results.

chlorine-ammonia treatment - The application of chlorine to water before or after the application of ammonia, to provide a persistent combined chlorine residual or to control the production of chlorinous tastes.

chlorine demand - The difference between the amount of chlorine added to water or wastewater and the amount of residual chlorine remaining at the end of a specified contact period. The demand for any given water varies with the amount of chlorine applied, time of contact, and temperature.

chlorine dioxide - An orange, water-soluble, unstable, extremely explosive gas, ClO_2. Used in water treatment primarily to remove tastes and odors. May also be used as a bleaching agent for wood pulp, fats, oils.

chlorine room - A separate room or building for housing chlorination equipment, with arrangements for protecting personnel and plant equipment.

chlorophenols - Phenolic compounds reacting with chlorine to produce additional products. Chlorophenols are capable of producing odors 10 to 1,000 times stronger than those of the unreacted phenols.

clarification - Any process or combination of processes the primary purpose of which is to reduce the concentration of suspended matter in a liquid.

clear-water reservoir - A reservoir for the storage of filtered water of sufficient capacity to prevent the necessity of frequent variations in the rate of filtration with variations in demands. Also called filtered-water reservoir, clear-water basin, clear well.

clear well - A reservoir for the storage of filtered water of sufficient capacity to prevent the necessity of frequent variations in the rate of filtration with variations in demands.

coagulant - A compound responsible for coagulation; a floc-forming agent.

coagulant aid - Any chemical or substance used to assist or modify coagulation.

coagulation - In water and wastewater treatment, the destabilization and initial aggregation of colloidal and finely divided suspended matter by the addition of a floc-forming chemical or by biological processes.

coliform-group bacteria - A group of bacteria predominantly inhabiting the intestines of man or animal, but also occasionally found elsewhere. It includes all aerobic and facultative anaerobics, Gram-negative, non-spore-forming bacilli that ferment lactose with production of gas. Also included are all bacteria that produce a dark, purplish-green colony with metallic sheen by the membrane-filter technique used for coliform identification. The two groups are not always identical, but they are generally of equal sanitary significance.

colloids - (1) Finely divided solids which will not settle but may be removed by coagulation or biochemical action or membrane filtration; they are intermediate between true solutions and suspensions. (2) In soil physics, discrete mineral particles less than two microns in diameter. (3) Finely divided dispersions of one material, called the dispersed phase, with another, called the dispersion medium. (4) In general, particles of colloidal dimensions are approximately 10 A to 1 u in size. Colloidal particles are distinguished from ordinary molecules by their inability to diffuse through membranes that allow ordinary molecules and ions to pass freely.

combined available chlorine - The concentration of chlorine which is combined with ammonia as chloramine or as other chloro derivitives, yet is still available to oxidize organic matter.

combined chlorine residual - combined available residual chlorine.

cone of influence - The depression, roughly conical in shape, produced in a water table or other piezometric surface by the extraction of water from a well at a given rate. The volume of the cone varies with the rate and duration of withdrawal of water. Also called cone of depression.

corrosion - The gradual deterioration or destruction of a substance or material by chemical action, frequently induced by electrochemical processes. The action proceeds inward from the surface.

corrosion control - (1) In water treatment, any method that keeps the discharge of the metallic ions of a conduit from going into solution, such as increasing the pH of the water, removing free oxygen from the water, or controlling the carbonate balance of the water. (2) The sequestration of metallic ions and the formation of protective films on metal surfaces by chemical treatment.

counterions - Ions of opposite charge.

cross-connection - (1) A physical connection through which a supply of potable water could be contaminated or polluted. (2) A connection between a supervised potable water supply and an unsupervised supply of unknown potability.

day tanks - Tanks holding one day's supply of a substance.

dead end - (1) The end of a water main which is not connected to other parts of the distribution system by means of a connecting loop. (2) In plumbing, a branch leading from soil, waste, or vent pipe, house drain, or house sewer, which is terminated at a developed distance of two feet or more by means of a cap, plug, or other closed fitting.

dechlorination - The partial or complete reduction of residual chlorine in a liquid by any chemical or physical process.

detention time - The theoretical time required to displace the contents of a tank or unit at a given rate of discharge (volume divided by rate of discharge).

dewater - (1) To extract a portion of the water present in a sludge or slurry. (2) To drain or remove water from an enclosure. A riverbed may be dewatered so that a dam can be built in the dry; (3) a structure may be dewatered so that it can be inspected or repaired.

diatomaceous-earth filter - A filter used in water treatment, in which a built-up layer of diatomaceous earth serves as the filtering medium.

discharge - (1) As applied to a stream or conduit, the rate of flow, or volume of water flowing in the stream or conduit at a given place and within a given period of time. (2) The passing of water or other liquid through an opening or along a conduit or channel. (3) The rate of flow of water, silt, or other mobile substance which emerges from an opening, pump, or turbine, or passes along a conduit or channel, usually expressed as cubic feet per second, gallons per minute, or million gallons per day.

disinfection - The art of killing the larger portion of microorganisms in or on a substance with the probability that all pathogenic bacteria are killed by the agent used.

dissolved oxygen - The oxygen dissolved in water, wastewater, or other liquid, usually expressed in milligrams per liter, parts per million, or percent of saturation. Abbreviated DO.

distribution reservoir - A reservoir connected with the distribution system of a water supply, used primarily to accommodate fluctuations in demand which occur over short periods (several hours to several days) and also to provide local storage in case of emergency such as a break in a main supply line or failure of a pumping plant.

distribution system - (1) A system of conduits and their appurtenances by which a water supply is distributed to consumers. The term applies particularly to the network or pipelines in the streets in a domestic water system and or to pipes and canals other than the main canal in an irrigation system. (2) The network used for distributing electrical power to consumers.

dose - (1) The quantity of substance applied to a unit quantity of liquid for treatment purposes. It can be expressed in terms of either volume or weight, e.g., pounds per million gallons, parts per million, grains per gallon, milligrams per liter, or grains per cubic meter. (2) Generally, a quantity of material applied to obtain a specific effect.

double check-valve assembly - An assembly composed of two single, independently acting check valves. An approved assembly includes tightly closing shut-off valves located at each end of the assembly and suitable connections for testing the watertightness of each check valve.

downflow - Direction of flow from a given vertical position to a lower vertical position.

drilled well - A well excavated wholly or in part by means of a drill (either percussion or rotary) which operates by cutting or by abrasion; the materials are brought to the surface by means of a bailer, sand pump, hollow drill tool, or by a hydraulic or self-cleaning method.

driven well - A well constructed by driving a casing, at the end of which there is a drive point, without the use of any drilling, boring, or jetting device.

drop light connection - electrical outlet for connection of extension cord.

dug well - A well excavated by means of picks, shovels, or other hand tools, or by means of a power shovel or other dredging or trenching machinery, as distinguished from one put down by a drill or auger.

dynamic head - (1) When there is flow: (a) the head at the top of a waterwheel; (b) the height of the hydraulic grade line above the top of a waterwheel; (c) the head against which a pump works. (2) That head of fluid which would produce statically the pressure of a moving fluid.

effective size - That size for which 10 percent of the grains are smaller and 90 percent larger.

effluent launders - Channels in a water tank into which the effluent from the tank flows.

electrodialysis - Process for removing ionized salts from water through the use of ion-selective ion-exchange membranes.

elevated tank - A tank, used for storage in a water distribution system, which is raised above the surface of the ground and is supported by posts or columns.

filter - A device or structure for removing solid or colloidal material, usually of a type that cannot be removed by sedimentation, from water, wastewater, or other liquid. The liquid is passed through a filtering medium, usually a granular material but sometimes finely woven cloth, unglazed porcelain, or specially prepared paper. There are many types of filters used in water or wastewater treatment.

filter bottom - (1) The underdrainage system for collecting the water that has passed through a rapid sand filter and for distributing the wash water that cleans the filtering medium. (2) The underdrainage system supporting the graded gravel of a biological bed. It may consist of specially fabricated tile or concrete blocks containing waterways and slots in the top for conveying the underdrainage, or it may consist of inverted half tile.

filter press - A press operated mechanically for partially separating water from solid materials.

filter run - The time interval between filter backwashes.

filter wash - The reversal of flow through a rapid sand filter to wash clogging material out of the filtering medium and reduce conditions causing loss of head. Also called backwash.

filtrate - The liquid which has passed through a filter.

floc - Small gelatinous massed formed in a liquid by the reaction of a coagulant added thereto, through biochemical processes, or by agglomeration.

flocculation - In water and wastewater treatment, the agglomeration of colloidal and finely divided suspended matters after coagulation by gentle stirring by either mechanical or hydraulic means. In biological wastewater treatment where coagulation is not used, agglomeration may be accomplished biologically.

flocculator - (1) A mechanical device to enhance the formation of floc in a liquid. (2) An apparatus for the formation of floc in water and wastewater.

flow - (1) The movement of a stream of water or other mobile substance from place to place; a stream of water; movement of silt, water, sand, or other material. (2) The fluid which is in motion. (3) The quantity or rate of movement of a fluid; discharge; total quantity carried by a stream. (4) To issue forth or discharge.

fluoridation - The addition of a chemical to increase the concentration of fluoride ions to a predetermined limit with a resulting reduction in the incidence of dental caries.

forced draft aeration - Positive draft using motor driven-fan or blower.

frazil ice - Fine spicules of ice found in water too turbulent for the formation of sheet ice.

free available chlorine - The amount of chlorine available as dissolved gas, hypochlorous acid, or hypochlorite ion that is not combined with an amine or other organic compound.

free available residual chlorine (free chlorine residual) - That portion of the total residual chlorine remaining in water or wastewater at the end of a specified contact period which will react chemically and biologically as hypochlorous acid or hypochlorite ion.

freeboard - The vertical distance between the normal maximum level of the surface of the liquid in a conduit, reservoir, tank, canal, etc., and the top of the sides of an open conduit, the top of a dam or levee, etc., which is provided so that waves and other movements of the liquid will not overtop the confining structure.

gravel-wall well - A type of well used in a water-bearing formation containing a large proportion of fine-grained material which permits the passage of water at low velocity. Gravel is introduced around the screen or intake section of the well to increase the specific capacity and to prevent extremely fine material from flowing into the well. Depending on detail of construction, such wells are called gravel well, gravel-envelope well, gravel-filled well, gravel-packed well.

gravity filter - A rapid sand filter of the open type, the operating level of which is placed near the hydraulic grade line of the influent and through which the water flows by gravity.

gridiron - A system of water pipes in which all pipes are connected with all other pipes at street intersections so that in case of a fire at any point, water comes to that point from all directions.

groundwater - (1) Subsurface water occupying the saturation zone, from which wells and springs are fed. In a strict sense the term applies only to water below the water table. Also called phreatic water, plerotic water.

Hardy Cross method - A method of analyzing flow in a water distribution system, devised by Hardy Cross in 1936; a mathematical analysis.

head - (1) The height of the free surface of fluid above any point in a hydraulic system; a measure of the pressure or force exerted by the fluid. (2) The energy, either kinetic or potential, possessed by each unit weight of a liquid, expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. It is used in various compound terms such as pressure head, velocity head, and loss of head. (3) The upper end of anything, as headworks. (4) The source of anything, as headwater. (5) A comparatively high promontory with either a cliff or steep face extending into a large body of water, such as a sea or lake. An unnamed head is usually called a headland.

head loss, initial - Head loss through a granular filter or carbon bed at the start of a run.

head loss, terminal - Head loss through a granular filter or carbon bed at the end of a run.

heavy metals - Metals that can be precipitated by hydrogen sulfide in acid solution, for example, lead, silver, gold, mercury, bismuth, copper.

holidays - Openings, defects, or imperfections in a coating of material.

hydraulic grade - In a closed conduit under pressure, artesian aquifer, or groundwater basin, a line joining the elevations to which water would rise in pipes freely vented and under atmospheric pressure. In an open channel, the hydraulic grade is the water surface.

hypochlorite - Calcium, sodium, or lithium hypochlorite.

hypochlorite of lime - A combination of slaked lime and chlorine in which calcium oxychloride is the active ingredient. Also called chlorinated lime.

impoundment - A pond, lake, tank, basin, or other space, either natural or created in whole or in part by the building of engineering structures, which is used for storage, regulation, and control of water.

in-channel storage dam - A dam constructed across or within the flowing channel of a stream or river.

induced draft aeration - Positive movement of air through an aerator by a motor driven fan taking suction from the aerator and discharging to atmosphere.

iodine number - The iodine number is the milligrams of iodine adsorbed by one gram of carbon at an equilibrium filtrate concentration of 0.02N iodine. It is measured by contacting a single sample of carbon with an iodine solution and extrapolating to 0.02N by an assumed isotherm slope. Iodine number can be correlated with ability to adsorb low molecular weight substances.

ion - A charged atom, molecule, or radical, the migration of which affects the transport of electricity through an electrolyte or, to a certain extent, through a gas. An atom or molecule that has lost or gained one or more electrons. By such ionization it becomes electrically charged. An example is the alpha particle.

ion exchange - (1) A chemical process involving reversible interchange of ions between a liquid and a solid but no radical change in structure of the solid. (2) A chemical process in which ions from two different molecules are exchanged.

I.P.S. - Interim Primary Standards, means the National Interim Primary Drinking Water Standards issued by the Administrator of EPA pursuant to the Safe Drinking Water Act, PL93-523.

lignin - An organic substance that, with cellulose, forms the chief part of woody tissue.

lime - Any of a family of chemicals consisting essentially of calcium hydroxide made from limestone (calcite) which is composed almost wholly of calcium carbonate or a mixture of calcium and magnesium carbonate.

loss-of-head gage - A gage, on a rapid sand filter, that indicates the loss of head involved in the filtering operation, whereby the operator is able to ascertain the need for filter washing. Some gages are of the indicating-recording type.

main - A water pipe line which is part of the principal water distribution grid (as contrasted to service pipe lines to serve individual premises).

mantle - The cover over bedrock; the loose rock and unconsolidated material covering the bedrock.

mean annual runoff - The average over a period of years of the annual amounts of runoff discharged by a stream.

membrane filter - A filter made of plastic with a known pore diameter. It is used in bacteriological examination of water.

mesh - One of the openings or spaces in a screen. The value of the mesh is usually given as the number of openings per linear inch. This gives no recognition to the diameter of the wire, and thus the mesh number does not always have a definite relation to the size of the hole.

mixing chamber - A chamber used to facilitate the mixing of chemicals with liquid or of two or more liquids of different characteristics. It may be equipped with a mechanical device for accomplishing the mixing.

molasses number - The molasses number is calculated from the ratio of the optical densities of the filtrate of a molasses solution treated with a standard activated carbon and the activated carbon in question. This is a test method of Calgon Corporation.

most probable number (MPN) - That number of organisms per unit volume that, in accordance with statistical theory, would be more likely than any other number to yield the observed test result or that would yield the observed test result with the greatest frequency. Expressed as density of organisms per 100 ml. Results are computed from the number of positive findings of coliform-group organisms resulting from multiple-portion decimal-dilution plantings.

natural draft aeration - Aeration by natural convection without use of motor driven fans or blowers.

negative pressure - A pressure less than the local atmospheric pressure at a given point.

NPDES - National Pollution Discharge Elimination System (of EPA).

off channel storage dam - A dam built off or outside the flowing channel of a stream or river.

OSHA - Occupational Safety and Health Act, 1970 (91-596).

outages - Interruption of operations or services.

ozone - Oxygen in molecular form with three atoms of oxygen forming each molecule (O_3).

Parshall flume - A calibrated device developed by Parshall for measuring the flow of liquid in an open conduit. It consists essentially of a contracting length, a throat, and an expanding length. At the throat is a sill over which the flow passes at Belanger's critical depth. The upper and lower heads are each measured at a definite distance from the sill. The lower head need not be measured unless the sill is submerged more than about 67 percent.

parts per million - The number of weight or volume units of a minor constituent present with each one million units of the major constituent of a solution or mixture. Formerly used to express the results of most water and wastewater analyses, but more recently replaced by the ratio milligrams per liter.

pathogenic bacteria - Bacteria which may cause disease in the host organisms by their parasitic growth.

peak demand - The maximum momentary load placed on a water or wastewater plant or pumping station or on an electric generating plant or system. This is usually the maximum average load in one hour or less, but may be specified as instantaneous or with some other short time period.

pH - The reciprocal of the logarithm of the hydrogen-ion concentration. The concentration is the weight of hydrogen ions, in grams, per liter of solution. Neutral water, for example, has a pH value of 7 and a hydrogenion concentration of 10^{-7}.

pitless units - Sanitary underground discharge piping system for wells that avoids the hazards common to well pits.

pipe gallery - (1) Any conduit for pipe, usually of a size to allow a man to walk through. (2) A gallery provided in a treatment plant for the installation of the conduits and valves and for a passageway to provide access to them.

plain sedimentation - The sedimentation of suspended matter in a liquid, unaided by chemicals or other special means and without provision for the decomposition of deposited solids in contact with the wastewater.

plankton - The aggregate of passively floating, drifting, or weakly motile organisms in a body of water. The organisms are mostly microscopic.

plate count - Number of colonies of bacteria grown on selected solid media at a given temperature and incubation period, usually expressed in number of bacteria per milliliter of sample.

porthole assembly - (1) A tank fixture which permits observation or entry; (2) An opening for a radial collector in a well caisson.

positive head - The energy possessed per unit weight of a fluid, due to its elevation above some datum. Also called elevation head.

postchlorination - The application of chlorine to water or wastewater subsequent to any treatment, including prechlorination.

potable water - Water that does not contain objectional pollution, contamination, minerals, or infective agents and is considered satisfactory for domestic consumption.

prechlorination - The application of chlorine to water or wastewater prior to any treatment.

presedimentation - Settling of silt and colloids prior to chemical coagulation, flocculation, and settling.

pressure - (1) The total load or force acting on a surface. (2) In hydraulics, without qualifications, usually the pressure per unit or intensity of pressure above local atmospheric pressure expressed, for example, in pounds per square inch, kilograms per square centimeter.

pressure filter - A rapid sand filter of the closed type, having a vertical or horizontal cylinder of iron, steel, wood, or other material inserted in a pressure line.

private water - Streams or other bodies of surface water that are not navigable or that are not publicly owned.

public water system - Means a system for the provision of piped water for human consumption, if such system has at least 15 service connections or regularly serves at least 25 individuals.

purveyor - (or water purveyor) The federal, state, county, city, town, municipal corporation, firm, company, mutual, cooperative, association, institution, person, or persons owning or operating a public water supply, or his authorized agent.

quicklime - A calcined material the major part of which is calcium oxide or calcium oxide in natural association with a lesser amount of magnesium oxide. It is capable of slaking with water.

radial well - A strainer well system in which many strainers are driven horizontally into a water-bearing stratum, radiating from a central sump or tube well.

radiation - The emission and propagation of energy through space or through a material medium; also, the energy so propagated.

radioactivity - The spontaneous decay or disintegration of an unstable atomic nucleus, accompanied by the emission of radiation.

rate-of-flow controller - An automatic device that controls the rate of flow of a fluid.

raw water - (1) Untreated water; usually the water entering the first treatment unit of a water treatment plant. (2) Water used as a source of water supply taken from a natural or impounded body of water, such as a stream, lake, pond, or underground aquifer.

recarbonation - (1) The process of introducing carbon dioxide as a final stage in the lime-soda ash softening process in order to convert carbonates to bicarbonates and thereby stabilize the solution against precipitation of carbonates. (2) The diffusion of carbon dioxide gas through liquid to replace the carbon dioxide removed by the addition of lime. (3) The diffusion of carbon dioxide gas through a liquid to render the liquid stable with respect to precipitation or dissolution of alkaline constituents.

recharge - Addition of water to the zone of saturation from precipitation, infiltration from surface streams, and other sources. Also see artificial recharge.

red water - Rust-colored water. Such color is usually due to the presence of precipitated ferric iron salts or to dead organisms the life processes of which depended on iron and manganese.

reservoir - A pond, lake, tank, basin, or other space, either natural or created in whole or in part by the building of engineering structures, which is used for storage, regulation, and control of water. Sometimes called impoundment.

residual pressure - Pressure in a main or hydrant under conditions of water flow or discharge.

responsible charge - The duties of the person responsible for directing operations of a system or plant.

reverse osmosis - Process for removing ionized salts from water by use of membranes which pass relatively pure water and retain relatively salty water.

safe yield - The maximum dependable draft that can be made continuously on a source of water supply (surface or groundwater) during a period of years during which the probable driest period or period of greatest deficiency in water supply is likely to occur. Dependability is relative and is a function of storage provided and drought probability.

scuttle - A small opening in a wall or roof furnished with a lid.

sedimentation - The process of subsidence and deposition of suspended matter carried by water, wastewater, or other liquids, by gravity. It is usually accomplished by reducing the velocity of the liquid below the point at which it can transport the suspended material. Also called settling.

service area - The area, district, or region served by a utility.

service connection - The individual pipeline between a water main and a structure which conveys water from the distribution system to the customer served.

short-circuiting - A hydraulic condition occurring in parts of a tank where the time of travel is less than the flowing-through time.

settling - The process of subsidence and deposition of suspended matter carried by water, wastewater, or other liquids, by gravity. It is usually accomplished by reducing the velocity of the liquid below the point at which it can transport the suspended material. Also called sedimentation.

sludge - (1) The accumulated separated from liquids, such as water or wastewater, during processing, or deposits on bottoms of streams or other bodies of water. (2) The precipitate resulting from chemical treatment, coagulation, or sedimentation of water or wastewater.

sludge dewatering - The process of removing a part of the water in sludge by any method such as draining, evaporation, pressing, vacuum filtration, centrifuging, exhausting, passing between rollers, acid flotation, or dissolved air flotation with or without heat. It involves reducing from a liquid to a spadable condition rather than merely changing the density of the liquid (concentration) on the one hand or drying (as in a kiln) on the other.

smooth-nose taps - Sampling taps without threads on the outlet.

sodium hexametaphosphate - Graham's salt; sodium 1:1 phosphate glass; sodium polyphosphate; glassy sodium phosphate. The molecule is currently considered to be an amorphous linear polymer of more than six units; in the past $(NaPO_3)_6$ had been given as the formula. It is soluble in water and insoluble in organic solvents. In general, it is used as a sequestering, dispersing, and deflocculating agent.

split treatment - The treatment of as large a part of water as possible by water softening and the subsequent neutralization of excess calcium hydroxide with untreated water or with water treated in a different manner.

stabilization - (1) Maintenance at a relatively noncluctuating level, quantity, flow, or condition. (2) In lime-soda water softening, any process that will minimize or eliminate scale-forming tendencies. (3) In waste treatment, a process used to equalize wastewater flow composition prior to regulated discharge. (4) In erosion control, treatment of dikes or shorelines with riprap, sod, penetrations, or similar protective devices. (5) In corrosion control, pH adjustment of water to maintain carbonate equilibrium at the saturation point.

standby plant - An electric power plant that is maintained in condition to produce power in case of emergencies, such as breakdowns occurring in the regular generating stations or transmission lines.

State - Means the agency of the State government which has jurisdiction over public water systems. During any period when a State does not have primary enforcement responsibility, the term "State" means the Regional Administrator, Environmental Protection Agency.

structural security - A structure which is safe against failure or damage from imposed loads.

submarine lines - Lines passing under water.

suction well - A pit or conduit containing water which serves as a source of supply for a pump.

sulfate-reducing bacteria - Bacteria capable of assimilating oxygen from sulfate compounds, thereby reducing them to sulfides.

surface wash - (1) A supplementary method of washing the filtering medium of a rapid sand filter by applying water under pressure at or near the surface of the sand by means of a system of stationary or rotating jets.

torpedo sand - Water filter sand placed between the supporting gravel and fine media, which consists of rather uniform spherical particles passing an 8-mesh and retained on a 16-mesh sieve.

total dynamic head - The difference between the elevation corresponding to the pressure at the discharge flange of a pump and the elevation corresponding to the vacuum or pressure at the suction flange of the pump, corrected to the same datum plane, plus the velocity head at the discharge flange of the pump, minus the velocity head at the suction flange of the pump.

total head - (1) The sum of the pressure, velocity, and position heads above a datum. The height of the energy line above a datum. (2) The difference in elevation between the surface of water at the source of supply and the elevation of the water at the outlet, plus velocity head and lost head. (3) The distance of the energy line above the datum; energy head. (4) In open-channel flow, the depth plus the velocity head.

trapped filter effluent - A filter effluent line which is water-sealed at its point of discharge and is otherwise so arranged that it does not drain when the filter is inoperative and the introduction of air into the filter effluent line is avoided.

turbidimeter - An instrument for measurement of turbidity, in which a standard suspension usually is used for reference.

turbidity - (1) A condition in water or wastewater caused by the presence of suspended matter, resulting in the scattering and absorption of light rays. (2) A measure of fine suspended matter in liquids. (3) An analytical quantity usually reported in arbitrary turbidity units determined by measurements of light diffraction.

turbine pump - A centrifugal pump in which fixed guide vanes partially convert the velocity energy of the water into pressure head as the water leaves the impeller.

ubiquitous - Existing or being everywhere at the same time.

uniformity coefficient - The ratio of filter media grain size that has 60 percent finer than itself to the size which has 10 percent finer than itself (effective size). This ratio thus covers the range in size of half the sand.

upflow - Direction of water flow in a filter or carbon bed in the service cycle of operation which is from bottom to top.

virgin carbon - Carbon which has been activated in the manufacturing process and is being used for adsorption for the first time; unregenerated carbon.

wash water - Water used to wash filter beds in a rapid sand filter.

wash-water tank - An elevated tank at a rapid sand filtration plant, into which water is pumped at a rate such that the tank will be filled between washings and set at a height such that the wash water will have a pressure of about 1 Kg/sq. cm. (15 psi) at the strainers.

wastewater - The spent water of a community. From the standpoint of source, it may be a combination of the liquid and water-carried wastes from residences, commercial buildings, industrial plants, and institutions, together with any groundwater, surface water, and storm water that may be present. In recent years, the word wastewater has taken precedence over the word sewage.

water analysis - The determination of the physical, chemical, and biological characteristics of water. Such analyses usually involve four different kinds of examinations: bacterial, chemical, microscopic, and physical.

water-borne disease - A disease caused by organisms or toxic substances carried by water. The most common water-borne diseases are typhoid fever, Asiatic cholera, dysentery, and other intestinal disturbances.

water demand - A schedule of the water requirements for a particular purpose, as for irrigation, power, municipal supply, plant transpiration, storage.

water main - The water pipe, located in a street, from which domestic water supply is delivered to the service pipe leading to specific premises.

watershed - (1) The area contained within a divide above a specified point on a stream. In water supply engineering, it is called a watershed or a catchment area; in river control engineering, it is called a drainage area, a drainage basin, or a catchment area. (2) The divide between drainage basins.

water supply source - A stream, lake, spring, or aquifer from which a supply of water is or can be obtained.

water supply system - (1) Collectively, all property involved in a water utility, including land, water source, collection systems, dams and hydraulic structures, water lines and appurtenances, pumping system, treatment works, and general properties. (2) In plumbing, the water distribution system in a building or complex of buildings, including appurtenances.

water system - Collectively, all of the property involved in the operation of a water utility, including land, water lines and appurtenances, pumping stations, treatment plants, and general property.

water treatment - The filtration or conditioning of water to render it acceptable for a specific use.

water treatment plant - That portion of water treatment works intended specifically for water treatment; may include, among other operations, sedimentation, chemical coagulation, filtration, and chlorination.

water well - An artificial excavation that derives water from the interstices of the rocks or soil which it penetrates.

weir - (1) A diversion dam. (2) A device that has a crest and some side containment of known geometric shape, such as a V, trapezoid, or rectangle, and is used to measure flow of liquid. The liquid surface is exposed to the atmosphere. Flow is related to upstream height of water above the crest, to position of crest with respect to downstream water surface, and to geometry of the weir opening. (3) A device at the inlet or outlet of a settling basin or filter over which water spills into or out of the basin or tank at a controlled level or elevation.

well capacity - The maximum rate at which a well will yield water under a stipulated set of conditions such as a given drawdown, pump and motor, or engine size. It may be expressed in terms of gallons per minute, cubic feet per second, or other similar units.

well interference - The phenomenon occuring when the water surfaces of the cones of depression of two or more wells come in contact with one another, thereby decreasing the yield of the wells. It is expressed quantitatively as the percentage reduction in yield of each well in terms of the capacity or yield uninfluenced by the others. It is commonly expressed as the decline in water level in feet in one well caused by pumping another well.

wetted carbon - Granular or powdered carbon which has been saturated with water; granular carbon will retain 40 percent moisture for prolonged periods of air drying.

yield - (1) The quantity of water, expressed as a rate of flow, that can be collected for a given use or uses from surface or groundwater sources on a watershed. The yield may vary with the use proposed, with the plan of development, and also with economic considerations. (2) Total runoff. (3) The streamflow in a given interval of time derived from a unit area of watershed, usually expressed in cubic feet per second per square mile.

zeolite - A group of hydrated aluminum complex silicates, either natural or synthetic, with cation-exchange properties.

APPENDIX B

TYPICAL JOB DESCRIPTIONS

Class Specifications

Class Title: Supt. of Water Treatment

DESCRIPTION OF DUTIES:

I. General Statement:

Under general supervision of the Sanitary Engineer, is responsible for the direction, administration, operation, and maintenance of the water treatment plants and the various units connected with them such as intake structures and reservoirs.

II. Typical Duties:

1. Supervises, plans, schedules, and directs the activities of assigned personnel engaged in treating raw water and the operation of intake structures and reservoirs.
2. Issues general instructions pertaining to operating procedures and maintenance work, and coordinates activities to meet operational needs.
3. Analyzes operating data, inspects operating units, and confers with Water Treatment Foremen on operational problems; prepares and submits reports to the Sanitary Engineer as required.
4. Confers with Board staff and plant personnel on matters affecting plant operations, changes, improvements, and construction programs; inspects and helps test completed projects before giving approval.
5. Interviews, selects and trains personnel in specific job methods and procedures, maintains the safety program, explains and administers established personnel policies and practices, and helps resolve employee grievances.
6. Authorizes purchase requisitions and inspects the storing and issuing of supplies and equipment.
7. Approves time sheets, payroll revisions, letters, overtime slips, injury reports, and is responsible for other clerical and administrative matters.
8. Prepares for review of an annual maintenance, capital improvement, and operation budget.

9. Performs related duties as assigned.

EXPERIENCE AND EDUCATION

Experience required:

Five years' experience in water works or treatment plant operation, at a level of complexity comparable to a foreman or administrative grade level position, with two years of extensive supervisory experience.

Graduation from a four-year college with major course work in chemistry, sanitary engineering, or a related field.

OR

Any equivalent combination of experience and education.

Class Specification

Class Title: Water Treatment Operator

DESCRIPTION OF DUTIES:

1. General Statement:

Under indirect supervision, operates a water treatment plant by determining and changing filtration rate, washing filters, making turbidity, pH, chlorine residual, taste and odor tests; operating dry feed chemical machine and chlorinators; and making and recording necessary meter and gauge readings; subject to rotating shift work, including weekends and holidays.

II. Typical Duties:

1. Determines and changes filtration rates according to demand.
2. Controls the quality of finished water by washing filters as required, adjusting dry feed machines, and performing other operations, including manually cleaning filter beds as required.
3. Runs and records tests such as raw and finished water turbidity, pH, chlorine residual, taste, odor and temperature.
4. Assists in maintaining proper elevations in raw and clear water reservoirs, reading and recording meters and gauges; changing meter recording charts and obtaining necessary raw and treated water samples.
5. Assists in logging and interpreting data between water treatment plants and the central dispatch office.
6. Fills dry feed chemical machine hoppers and regulates and records their operation.
7. Maintains equipment and tools in good working condition and maintains neat and orderly work areas reporting the need for repairs and assists Water Treatment Plant Foreman and other personnel in making emergency repairs.
8. Under supervision, changes chlorine tanks when empty; checks chlorine machines and connections for leaks.
9. Responsible for carrying out the Department safety program through job performance and attendance at scheduled safety meetings.
10. Performs related duties as assigned.

EXPERIENCE AND EDUCATION:

Experience required:

Four years' experience in water treatment work.

Education required:

Graduation from high school, supplemented by a one year course in water treatment plant techniques. Must possess Colorado Class "C" Water Treatment Plant Operator Certification.

OR

Any equivalent combination of experience and education with a Colorado Class "C" Water Treatment Plant Operator's Certification.

Class Specification

Class Title: Quality Control Engineer

DESCRIPTION OF DUTIES:

I. General Statement:

Under general supervision is responsible for the direction, administration, and operation of the Quality Control Section.

II. Typical Duties:

1. Supervises, plans, schedules, and directs the activities of assigned personnel engaged in quality control laboratory, cross-connection abatement, system sterilization and watershed patrol.
2. Prepares comprehensive and detailed technical reports with recommendations for formulation of policies, plans and procedures.
3. Maintains personal contact with the public regarding services and complaints, investigates and resolves water quality problems and maintains good public relations consulting with City, State and Federal Public Health Agencies.
4. Interprets routine and special laboratory analyses relating to water purification and quality control and performs difficult or unusual laboratory analyses, special tests and examinations.
5. Reviews and evaluates existing treatment processes, laboratory methods and conducts research into new techniques and procedures.
6. Estimates and requisitions materials, supplies and equipment necessary for the operation of the Quality Control Section.
7. Interviews, selects, and trains personnel in specific job methods and procedures, maintains a safety program; explains and administers established personnel policies and practices, and helps resolve employees grievances.
8. Assists in the preparation of an annual maintenance, capital improvement, and operation budget.
9. Performs related duties as required.

EXPERIENCE AND EDUCATION:

Experience required:

Six years supervisory experience in water quality field, sanitation and other related activities.

Education required:

Graduation from an approved college with a major in Sanitary Engineering or Water Chemistry.

OR

Any equivalent combination of experience and education.

Class Specification

Class Title: Microbiologist II

DESCRIPTION OF DUTIES:

I. General Statement:

Under supervision, conducts microbiological examinations of water and other materials pertinent to water pollution, purification and distribution, and conducts research studies as required.

II. Typical Duties:

1. Performs and supervises the performance of Quality Control Technicians performing routine microbiological analyses for contaminating organisms in samples of water collected from water purification and distribution system.
2. Examines, enumerates and identifies species of plankton and significant plant life found in reservoir water samples.
3. Assists in developing section operating programs and procedures.
4. Isolates and identifies by genera and species, microbiological organisms cultured from water samples and performs serological techniques to identify origin of bacterial contamination.
5. Research scientific literature to keep laboratory operations abreast of latest developments in field.
6. Conducts analytical research studies and prepares general and statistical reports as required.
7. Maintains microbiological laboratory techniques, materials and equipment in accordance with Federal and State standards.
8. Performs related duties as required.

EXPERIENCE AND EDUCATION:

Experience required:

Two years in microbiological analysis of water.

Education required:

Graduation from an accredited college or university with a degree in Microbiology.

OR

Any equivalent combination of experience and education.

Class Specification

Class Title: Chemist II

DESCRIPTION OF DUTIES:

I. General Statement:

Under general supervision, performs chemical and microscopical analyses of water and all materials used in water treatment; develops details of research assignments according to established procedures, and adapts methods to the specific requirements of assignments.

II. Typical Duties:

1. Initiates and interprets general, periodic and special analyses of water.
2. Reviews environmental aspect of chemical treatment processes, preparing standardizing solutions used in making chemical tests at the laboratory and in treatment plants.
3. Assists in developing section operating programs and procedures.
4. Prepares reagents, sets up apparatus for analytical procedures; standardizes and calibrates instruments; adapts equipment for field sampling; repairs new and old equipment.
5. Investigates consumer complaints regarding water quality.
6. Studies scientific literature for recent developments; catalogs data and information for reference; inventories stock and equipment; assists with research work in the field of public health.
7. Keeps records relating to chemical tests, quality complaints, etc.
8. Performs related duties as assigned.

EXPERIENCE AND EDUCATION:

Experience required:

Two years of experience in water chemistry.

Education required:

Graduation from college with four-year degree in Chemistry.

OR

Any equivalent combination of experience and education.

Class Specification

Class Title: Superintendent of Maintenance

DESCRIPTION OF DUTIES:

I. General Statement:

Under general direction of the Chief of Plant, plans, manages, directs and supervises the complete operation and maintenance of various craft shops engaged in construction and maintenance and of the yard crew engaged in loading, unloading, and transporting various supplies.

II. Typical Duties:

1. Supervises, plans, schedules and directs the activities of semi-skilled and skilled crafts personnel engaged in carpentry, blacksmithing, machining, painting, auto and equipment repairing, plumbing, mechanical maintenance and installation, electrical work and welding and miscellaneous duties.

2. Confers with and advises subordinate personnel on output requirements, maintenance and operating work schedules; the utilization and training of personnel, personnel relations and other matters, and coordinates activities of the work force.

3. Confers with Board staff and other division superintendents to coordinate services and to resolve problems with a minimum of delay. Also supervise and maintain communication systems.

4. Reviews existing policies, procedures and work methods by means of periodic inspections of the shops, insuring that methods of operation are adequate and reviews requirements, present and future, to provide adequate space, equipment, and personnel.

5. Supervises the establishment and maintenance of a regular maintenance program on Water Department equipment and buildings.

6. Prepares for review an annual operational, maintenance, and capital improvement budget for the Maintenance Section and determines transportation and M-Equipment needs for Water Department budget.

7. Interviews, selects and supervises the training of personnel in specific job methods and procedures, safety program, explains and administers established personnel policies and practices, and resolves employee grievances.

8. Reviews time sheets, payroll revisions, letters, overtime slips, injury reports, being responsible for clerical and administrative matters.

9. Performs related duties as required.

EXPERIENCE AND EDUCATION:

Experience required:

Nine years' experience in general plant and equipment maintenance, including two years in a responsible supervisory position.

Education required:

Graduation from high school supplemented by two years of mechanical engineering.

OR

Any equivalent combination of experience and education.

Class Specification

Class Title: Building Maintenance Supervisor

DESCRIPTION OF DUTIES:

I. General Statement:

Under general supervision, is responsible for the departmental building maintenance function, including the operation of heating and air conditioning units, maintenance and repair of main office and west side buildings, fixtures and furnishings.

II. Typical Duties:

1. Responsible for the operation of heating and air conditioning units, regulating the intake of fresh or cool air with heated air to maintain a proper balance of fresh air in buildings.

2. Supervises the scheduling and work planning of janitors at all locations, being responsible for general cleanliness and employee relations.

3. Regulates and maintains on a daily basis, individual blower units, freeze-protection units, chiller units and coordinates contract services such as window cleaning and elevator maintenance.

4. Periodically checks hydraulic door units, belts on air conditioning units and air handling unit filters.

5. Performs minor repair and maintenance on such items as chairs, desks, telephone fixtures, venetian blinds, windows, light fixtures, parking lot blocks, sidewalks, stairs, rails, floor tiles, etc.

6. Notifies electricians, mechanics, carpenters, painters, or plumbers for more difficult maintenance such as ballast repair, ammonia tank replacement, map frames and racks, and painting projects.

7. Prepares and retains records of materials, supplies, equipment and labor required in the pursuance of duties.

8. Performs related duties as assigned.

EXPERIENCE AND EDUCATION:

Experience required:

Four years of experience performing work of a janitorial and mechanical nature, with knowledge of heating, air conditioning systems and minor appliance repair.

Education required:

Graduation from high school.

OR

Any equivalent combination of experience and education.

Class Specification

Class Title: Instrument Technician

DESCRIPTION OF DUTIES:

I. General Statement:

Under supervision, performs highly skilled electrical and mechanical work required in designing, installing, testing, repairing and maintaining a variety of in-plant metering equipment, remote controlled devices, and related equipment.

II. Typical Duties:

1. Designs, installs, tests, repairs and maintains complex electrical and mechanical equipment such as meters, telemeters, integrators, tone control equipment, and remote controlling devices, including relays, rectifiers, bubbler systems, manometers, etc.
2. Performs necessary tests on the above mentioned equipment with the aid of various instruments such as the volt-ohmeter, oscilloscope, tone generator, Wheatstone bridge megger, metameter timer, etc.
3. Inspects above mentioned equipment, diagnosing trouble which may occur in connection with equipment operation, and follows through with necessary corrective action making electrical sketches of installations for future reference.
4. Disassembles equipment and replaces worn and defective parts; reassembles equipment, making the necessary adjustments and conducting the necessary tests.
5. Assists in the instruction and training of lesser grade employees.
6. Directs cleaning of equipment and work areas, and may direct the work of lesser grade employees.
7. Responsible for carrying out the Department safety program through job performance as well as attendance at all scheduled safety meetings.
8. Performs related duties as assigned.

EXPERIENCE AND EDUCATION:

Experience required:

Five years in the installation, repair, and maintenance of electrical equipment, and must possess, or obtain in a specified time period, a Journeyman Electrician's License. Must possess a Chauffeur's License.

Education required:

Graduation from high school, supplemented by vocational training in electrical courses.

OR

Any equivalent combination of experience and education.

Class Specification

Class Title: Electrician

DESCRIPTION OF DUTIES:

I. General Statement:

Under supervision performs skilled work in the wiring for installation, maintenance and repair of electrical apparatus and auxiliary equipment for light, heat, power and other purposes. Will maintain, install, repair, and inspect equipment ranging from 110 volts to 4,000 volts, power lines from 200 volt to 69,000 volt and related generating and controlling equipment.

II. Typical Duties:

1. Installs, tests, repairs and maintains complex electrical equipment such as rotating equipment, breakers, induction regulators, transformers, controllers, electronic devices, relays, busways, motors, and generators.

2. Inspects electrical equipment diagnosing trouble which may occur in connection with equipment operation.

3. Disassembles equipment and replaces worn and defective parts; reassembles equipment, makes necessary adjustment and conducts performance tests with the aid of standard testing devices and climbs poles in the performance of such duties.

4. Installs, repairs and maintains in buildings and outdoors, electrical equipment working from blue prints and sketches, replacing existing wiring systems.

5. Sets up necessary rigging in the handling of equipment and materials.

6. Makes sketches of parts to be repaired or fabricated.

7. Supervises the work of lesser-grade employees and is responsible for carrying out the Department safety program through job performance and attendance at scheduled safety meetings.

8. Performs related duties as assigned.

EXPERIENCE AND EDUCATION:

Experience required:

Five years of experience and must possess or obtain in a specified time period, a Journeyman's Electrician License. Must possess Chauffeur's License.

Education required:

Graduation from high school, supplemented with vocational training in electrical duties.

OR

Any equivalent combination of experience and education.

Class Specification

Class Title: Maintenance Mechanic

DESCRIPTION OF DUTIES:

I. General Statement:

Under supervision, performs a variety of maintenance jobs such as installing, servicing, and repairing pumps, compressors, meters, chemical dry feed machines, electric motors, etc., requiring some ability to do welding, sheet metal work, painting, carpentry, pipe fitting, and cement work.

II. Typical Duties: (Any one position may not include all of the duties listed nor do the listed examples include all tasks which may be found in positions of this classification.)

1. Repairs and maintains equipment such as pumps, compressors, dry feed machines, electrical meters, chlorinators, valves, gauges, small tools, etc.
2. Installs and regulates a variety of mechanical equipment used in the Water Department.
3. Installs, maintains and repairs parts of buildings and structures in the Water Department, including overhead cranes and hydraulic systems.
4. Performs general maintenance on plant heating and plumbing systems.
5. Assists in shops performing related mechanical duties when necessary.
6. Maintains equipment and tools in good working order and keeps a neat working area.
7. Responsible for carrying out the Department safety program through job performance and attendance at schedules safety meetings.
8. Performs related duties as assigned.

EXPERIENCE AND EDUCATION:

Experience required:

Four years' experience in building and mechanical maintenance work. Must possess Chauffeur's License.

Education required:

Graduation from high school, supplemented by six months mechanical or hydraulic training.

OR

Any equivalent combination of experience and education.

Class Specification

Class Title: Distribution Supervisor

DESCRIPTION OF DUTIES:

I. General Statement:

Under general supervision directs and coordinates job scheduling, personnel and equipment in various fields of water works construction and maintenance and is responsible for coordinating construction activities with other utilities, traffic engineering, and the public; supervising and directing personnel in proper and safe construction methods, being responsible for Water Department activities within a geographical district.

II. Typical Duties:

1. Responsible for supervising and scheduling the work for crew foreman and equipment operators.
2. Supervises the operation and maintenance of power equipment, charging to proper accounts and supervises the use of, and procures tools and equipment used.
3. Responsible for safety of personnel and equipment utilized on construction sites and the safety of the general public during and after construction work until the site is restored to its former condition.
4. Coordinates and helps plan work between other utility companies such as Public Service, telephone company, traffic engineers, City and County engineers, and contractors, concerning hazards or interferences which arise on particular projects.
5. Maintains records of all projects in the district, reporting and advising changes, methods and ways to accomplish work, maintaining all pertinent work and pipe maps.
6. Works with and advises the public of situations around projects such as service disruptions, discussing and correcting any problems which might arise, explaining results and aiding consumers in any possible way.
7. Knows and instructs personnel regarding the Water Department Employees Manual, Chief Engineers Standards and Rules and Regulations Manual, or refers questions to the appropriate section.
8. Performs related duties as assigned.

EXPERIENCE AND EDUCATION:

Experience required:

Six years' experience in the installation, maintenance and repair of pipelines. Must possess a Chauffeur's License.

Education required:

Graduation from high school with advanced vocational and management training courses.

OR

Any equivalent combination of experience and education.

Class Specification

Class Title: Superintendent of Water Control

DESCRIPTION OF DUTIES:

I. General Statement:

Under general supervision of the Chief of Plant, is responsible for the operation of the city distribution system and controls the flow of filtered water into and throughout the distribution system; plans and supervises the operation of all pumping stations and distribution reservoirs, and supervises assigned personnel directly or by delegation.

II. Typical Duties:

1. Supervises, plans and directs the work of assigned personnel in the operation of the water distribution system, controlling the flow of water from treatment plants throughout the system to provide volume and pressure.
2. Provides general instructions for operation of pump stations, distribution reservoirs and establishes operating procedures to meet these operational requirements.
3. Supervises and directs the activities of the water servicemen providing quality water service on a 24-hour basis including rendering consumer and public assistance as required.
4. Assists, recommends and confers with personnel of other sections and divisions of the Board on matters affecting systems operation, changes and improvements, as they affect the pumping, reservoirs and water distribution system.
5. Interviews, selects and trains personnel in specific job methods and procedures, maintains safety program and explains and administers established personnel policies and practices and resolves employee grievances.
6. Maintains records and charts on the water distribution system for analysis and historical purposes and approves time sheets, accident reports, overtime, requisitions and other administrative matters.
7. Prepares a yearly operation, maintenance and capital budget for the Water Control Section.
8. Performs other duties as assigned.

EDUCATION AND EXPERIENCE:

Experience required:

Six years' experience in operation of distribution systems, pump stations and regulating reservoirs with two years of supervisory experience.

Education required:

Graduation from college with a degree in electrical, mechanical or related engineering field.

OR

Any equivalent combination of experience and education.

Class Specification

Class Title: Water System Operator

DESCRIPTION OF DUTIES:

I. General Statement:

Under indirect supervision, controls the flow of treated water into and throughout the distribution system, acting as coordinator between treatment plants, pumping stations, and clear water reservoirs to obtain the most efficient water use, reacts to emergency fire calls, pressure complaints and system leaks.

II. Typical Duties: (Any one position may not include all of the duties listed nor do the listed examples include all tasks which may be found in positions of this classification.)

1. Responsible for maintaining adequate pressure and flow of treated water into and throughout the distribution system including the scheduled usage and replenishment of terminal storage reservoirs in coordination with treatment plant output and pump station capacities.
2. Responsible for logging and interpreting data between pumping stations, water treatment plants, satellite stations and the central control office.
3. Operates the Datalogger console teletype and teletypewriter to display system information, interpret computer output and analyze all data for the most practical and efficient operation.
4. Responsible for the operation of computer terminals to execute programmed control aids for forecasting water use, pumping demand, historic operations and water use, interpreting programs and outlets for the most practical operation.
5. Responsible for operating all feeds and regulations into and out of all pressure regulating valves, pumping stations, reservoirs and other valve operations.
6. Operates the system to meet emergency conditions, such as fires, extremely high or low pressures, leaks, and water outages, working closely with the Fire Department and other Water Department personnel.
7. Gathers and distributes weather information, water use and system condition information from and for other Water Department sections.
8. Performs related duties as assigned.

EXPERIENCE AND EDUCATION:

Experience required:

Six years' experience related to water distribution with two years of this experience including computerized control techniques and procedures.

Education required:

Graduation from high school supplemented by two years' vocational training related to circuitry, hydraulics, computer science or related field.

OR

Any equivalent combination of experience and education.

Class Specification

Class Title: Water Distribution Foreman II

I. General Statement:

Under general supervision, supervises and directs a construction crew of personnel performing a variety of semi-skilled to skilled duties pertaining to the operation, maintenance, and construction of the distribution system, including raw water conduits and ditches; being responsible for safe operations.

II. Typical Duties:

1. Supervises the work of laborers, giving detailed instruction and training in job duties and requirements, following up and inspecting operating and maintenance work and checking job methods and the use of tools and equipment insuring proper safety.

2. Supervises the duties of pipeline and hydrant and valve mechanics in the installation and repair of pipelines, hydrants, valves and vault maintenance and construction, including instructions regarding the use of tools and equipment.

3. Maintains good public relations and working contacts as necessary with the general public, homeowners, contractors, other utilities and Department personnel.

4. Supervises the performance of such duties as digging, shoring trenches, lifting, carrying, backfilling, mixing concrete, operating equipment, grounds and road repairing, and snow removal.

5. Reviews work maps for interference, digs test holes and determines proper site location.

6. Maintains records such as time, supplies and materials; requisitions tools and equipment needed for jobs in advance and must know and instruct personnel in the Water Department manual, as well as the Chief Engineer's Standards and Rules and Regulations manual.

7. Responsible for carrying out the Department safety program through job performance and attendance at scheduled safety meetings.

8. Performs related duties as assigned.

EXPERIENCE AND EDUCATION:

Experience required:

Six years' experience in the installation, maintenance and repair of pipelines. Must possess a Chauffeur's License.

Education required:

Graduation from high school, supplemented with appropriate supervisory development programs.

OR

Any equivalent combination of experience and education.

Class Specification

Class Title: Meter Reading Supervisor

DESCRIPTION OF DUTIES:

I. General Statement:

Under supervision is responsible for Customer Servicemen in the reading of meters; preparing meter reading schedules, daily work schedules, follow-up work; assists in dispatching of mobile radio units, checking records of completed work and recording consumption figures in meter reading decks.

II. Typical Duties:

1. Prepares meter reading and daily work schedules analyzing reading decks at end of each reading period for consumption variation, skip readings, locked and vacant premises, non-registering meters, leaks, acts of vandalism, accessibility, etc.
2. Supervises field investigations for causes of excessive water usage or drops in consumption; investigates illegal connections, and leaks in meter at inlet, outlet, or spindle.
3. Inspects and advises consumers of inaccessible meters, maintaining written and verbal communication until situation is corrected.
4. Responsible for implementing an effective safety program; investigates difficulties reported by, or against meter reading personnel; files reports regarding conditions found, and corrective action taken or recommended.
5. Assists the Revenue Service Supervisor in the training and development of Customer Servicemen including field assistance as required.
6. Performs related duties as assigned.

EXPERIENCE AND EDUCATION:

Experience required:

Four years of experience in meter reading and installation functions.

Education required:

Graduation from high school

OR

Any equivalent combination of experience and education.

Class Specification

Class Title: Water Serviceman II

DESCRIPTION OF DUTIES:

I. General Statement:

Under indirect supervision, inspects and operates pump, valve and water control stations, responds to consumer, fire and similar calls. Performs and trains personnel in direct contact with the public, consumers and other utilities in regards to water disturbances and construction. Performs a variety of duties in the operation of the city distribution system; subject to rotating shift work, including weekends and holidays.

II. Typical Duties: (Any one position may not include all of the duties listed nor do the listed examples include all tasks which may be found in positions of this classification.)

1. Inspects Transmission and Distribution camp sites and construction projects, works closely with the Transmission and Distribution Section on large main outages.

2. Relieves dispatchers, water system operators and assistants when necessary performing some or all of the duties of operating the distribution system aiding in water and electric load shifting operation and analyzing cost of same.

3. Aids the fire department in any way necessary in the event of a serious fire, etc.

4. Inspects pumps, valves, reservoirs and other pertinent work control stations to insure adequate maintenance of these facilities, logging and interpreting all maintenance data.

5. Operates hydrants, checks and records pressure on fire hydrants, and directs personnel in fire flow tests, recording all flow and pressure data for each station changing telemetry charts and checking station environment conditions to prevent overheating, flooding, or power overloading.

6. Makes direct contact with the public to determine responsibility for leak repairs.

7. Responsible for and trains employees in initiating reports of all inspections, investigations pertaining to vaults and leaks on both private and public property.

8. Responsible for instructing employees in barricading, lighting and policing emergency work and general construction sites.

9. Assists other employees in the operation of transistorized leak and pipe detection equipment necessary in water service operations.

10. Responsible for carrying out the Department safety program through job performance and attendance at scheduled safety meetings.

11. Performs related duties as assigned.

EXPERIENCE AND EDUCATION:

Experience required:

Three years' experience related to the distribution system with basic knowledge of electric circuits and hydraulics. Must possess Chauffeur's License.

Education required:

Graduation from high school.

OR

Any equivalent combination of experience and education.

Class Specification

Class Title: Utility Worker II

DESCRIPTION OF DUTIES:

I. General Statement:

Under general supervision, performs a variety of semi-skilled duties related to the operation of all divisions of the Water Department; subject to rotating shift work, including weekends and holidays.

II. Typical Duties: (Any one position may not include all of the duties listed nor do the listed examples include all tasks which may be found in positions of this classification.)

1. Performs semi-skilled and diverse duties such as digging, lifting, backfilling, mixing and finishing concrete, rock drilling and blasting, laying and connecting pipe, road repair, tree cutting and snow removal.
2. Operates a variety of equipment such as light trucks, pavement breakers, tampers, tractor-mowers, loaders, road patrol, bulldozer, jackhammer, rock drilling and blasting equipment, and related equipment; maintains and lubricates all related equipment utilized by the respective sections.
3. Responsible for the unrestricted flow of water in respective canals and ditches, maintaining satisfactory relationships with respective users of irrigation water and adjacent landowners; must implement water flow policy in a manner that constitutes satisfactory public relations with the Water Department.
4. Assists employees of higher crafts or skills in the performance of special or regularly-assigned work as directed.
5. Keeps tools, equipment, and work area in a clean, orderly and safe condition.
6. Is responsible for carrying out the Department safety program through performance as well as through attendance at scheduled safety meetings.
7. Performs related duties as assigned.

EXPERIENCE AND EDUCATION:

Experience required:

Two years of related experience including a wide variety of equipment operations; must have Chauffeur's License.

Education required:

Graduation from high school.

OR

Any equivalent combination of experience and education.

Class Specification

Class Title: Safety Director

DESCRIPTION OF DUTIES:

I. General Statement:

Under the general supervision of the Personnel Manager is responsible for the implementation and execution of the Board of Water Commissioners safety program; complying with requirements of the Occupation Safety and Health Act; investigating and documenting accidents arising out of Water Department operations; including processing and control of all Workmen's Compensation claims.

II. Typical Duties:

1. Makes periodic inspection tours to determine and evaluate conditions that may produce accidents, or be potential employee health hazards, or effect the safety of the general public.

2. Conducts thorough investigations of accidents and possible damage claims arising out of Water Department operations; completing detailed reports and making the information available as required.

3. Conducts safety meetings at all departmental levels; instructing employees in regard to Water Department safety policies; organizes and supervises first aid instruction courses.

4. Recommends work practices, new safety devices, or equipment modifications necessary to correct potentially dangerous conditions; makes progress reports on recommendations.

5. Continually checks to see that established safety procedures are followed, that safety equipment is used correctly, and prepares monthly safety bulletins.

6. Supervises the compilation of statistical safety reports, safety bulletins and related material; keeping abreast of current developments on safety programs on a national level, and participates in water utility safety programs of AWWA.

7. Acts as a liaison man for the Personnel Section to Water Department employees on many general personnel problems including matters pertaining to the health and safety of Water Department employees.

8. Performs related duties as assigned.

EXPERIENCE AND EDUCATION:

Experience required:

Three years of experience in industrial safety with knowledge of accident prevention and safety procedures in the water utility field.

Education required:

Graduation from college with a degree in business, Public Administration, or a related field.

OR

Any equivalent combination of experience and education.

Class Specification

Class Title: Personnel Manager

DESCRIPTION OF DUTIES:

I. General Statement:

Under the administrative direction of the Director of Administration and Public Affairs, is responsible for formulation and the administration of the Water Department Personnel Program. This position is created and established in accordance with the Charter of the City and County of Denver as a classification of employment and persons having executive discretion who shall serve solely at the pleasure of the Board.

II. Responsibilities:

1. Supervise, coordinate, and direct the activities of assigned personnel to provide for the establishment and maintenance of proper personnel policies, procedures and practices, and carry out all personnel policies and rules adopted by the Board.

2. Plan, develop, promulgate, and maintain personnel management policies, standards, guides, records, forms and procedures to establish and maintain effective personnel policies and practices.

3. Direct and administer the Department's classification plan; perform position audits and allocate positions in the classified service to classes within the plan.

4. Direct and administer the Department's pay plan; to conduct annual wage studies and to recommend any necessary or advisable revisions in the pay plan in final form as to be suitable for submission to the Board.

5. Direct and administer the interviewing and screening of job applicants; prepare and hold examinations, pass upon qualifications of applicants; establish eligibility lists and certify eligible applicants to supervisors.

6. Provide such central personnel management services as maintaining personnel records, planning and coordination of employee service, health and hospitalization plans, Water Department benefit plans, employee testing, suggestion system and information.

7. Formulate, develop and administer procedures and plans for employee training programs.

8. Supervise and implement the safety program by coordinating and guiding the activities of the Safety Director in planning for training programs and other duties.

9. Develop and administer plans and procedures for establishing standards of efficiency for classified employees measuring employee performance against such standards, and using such measurements as a basis for personnel action.

10. Investigate the operation and effect of personnel policies and rules as established or approved and report findings and recommendations revisions to management.

11. Perform personal counseling duties with Water Department employees; conduct employee grievance hearings; coordinate employee grievance procedures with supervisory personnel and act in reviewing capacity on employee grievance and suspension hearings.

12. Direct routine office procedures, answers correspondence and requests for information on personnel policies and is responsible for other clerical and administrative matters.

13. Keep abreast of current labor laws and personnel developments in such fields as communications, morale, training, and wage and salary administration and weighs their effect and merit with regard to Water Department personnel administration.

14. Perform related duties as required.

EXPERIENCE AND EDUCATION:

Experience required:

Ten years experience in personnel work or related field with at least three years on a supervisory level.

Education required:

Graduation from college with a degree in Business or Public Administration or equivalent, with emphasis in management or personnel work.

Class Specification

Class Title: Training Officer

DESCRIPTION OF DUTIES:

I. General Statement:

Under general supervision of the Personnel Manager is responsible for administrative and professional work in planning, developing and coordinating employee training program.

II. Typical Duties:

1. Plans, develops and conducts in-service and orientation training, supervisory, management development, and other training, evaluating the training program for effectiveness.

2. Coordinates training efforts with operating divisions and sections by advising and assisting in determining training needs and recommends methods for meeting training requirements; establishes training programs to enable employees to be placed on eligibility lists when qualified after training.

3. Evaluates training needs in order to develop educational material and to act as a source for training aids to assist the operating divisions and sections.

4. Coordinates training through available resources at educational institutions and the organizations offering employee training; secures services of subject matter specialists; advises and assists instructors in establishing course content, obtaining materials and equipment, and in conducting courses.

5. Determines which training programs will be carried on internally and which shall be accomplished by contractual arrangements with outside sources.

6. Performs research relating to course preparation and presentation, compiles data for use in writing manuals, handbooks and other training aids required for courses.

7. Develops teaching outlines and lesson plans; determines content and duration of courses and selects appropriate instruction procedures.

8. Prepares and disseminates informational materials to promote understanding and support of training programs such as brochures, pamphlets and course outlines; counsels employees on available and appropriate training for development and advancement.

9. Handles all phases of the Board's tuition refunding programs, and makes recommendations as required.

10. Evaluates process of employees to determine effectiveness of training methods, materials and courses.

11. Performs related duties as assigned.

EXPERIENCE AND EDUCATION:

Experience required:

Five years of training experience with a minimum of two years designing, developing and implementing general, supervisory and administrative training programs.

Education required:

Graduation from an accredited four-year college or university with major course work in Personnel Administration, Public Administration or Business Administration.

OR

Any equivalent combination of experience and education.

Class Specification

Class Title: Manager of Accounting

DESCRIPTION OF DUTIES:

I. General Statement:

Under the general direction of the Chief, Commercial Division, is responsible for administering the overall accounting function for the Water Department.

II. Typical Duties:

1. Supervises, plans, schedules and directs, the activities of assigned personnel performing the functions of disbursements, ledgers, audit coordination, property accounting, accounts receivable and cashering.

2. Develops and issues general instructions pertaining to procedural activities and coordinates the various accounting functions as they relate to each other, and also as they relate to other divisions and sections of the Water Department.

3. Responsible for developing and maintaining accounting systems and records, and for the preparation of periodic and special reports to Management and various divisions and sections of the Department for use in controlling their operations; provides and maintains such records as required by other divisions or sections in the performance of their functions.

4. Confers with Board staff on matters affecting the Accounting Section; reviews and evaluates existing policies, procedures, operating costs, work methods, and organizational needs in the Accounting Section by means of periodic and special reports; prepares recommendations to the Chief of the Commercial Division.

5. Responsible for employee selection, training, administering established personnel policies and practices, reviewing and evaluating personnel requirements and performance.

6. Directs routine office procedures and approves time sheets, payroll revisions, overtime, etc.

7. Prepares the annual operation, maintenance, and capital budget for the Accounting Section; develops and reviews existing and proposed E.D.P. accounting systems for adaptation and modification as required.

8. Performs related duties as required.

EXPERIENCE AND EDUCATION:

Experience required:

Six years of general accounting experience, including two years in a responsible supervisory position.

Education required:

Graduation from an accredited four-year college with a degree in Business Administration, Public Administration or related field with major course work in accounting.

OR

Any equivalent combination of experience and education.

APPENDIX C

WHERE REFERENCED DOCUMENTS AND STANDARDS CAN BE OBTAINED

1. All AWWA (American Water Works Association) publications (see AWWA Yearbook, 1975 for listing) can be obtained from:

   American Water Works Association
   Publications Order Department
   6666 W. Quincy Avenue
   Denver, Colorado 80235

2. Fire Protection Information including "Rating Schedules for Municipal Fire Protection" and "Guide For Determination of Required Fire Flow", can be obtained from:

   Insurance Services Office
   160 Water Street
   New York, New York 10038

   (formerly National Board of Fire Underwriters)

3. Federal publications can be obtained from:

   Supt. of Documents
   U.S. Government Printing Office
   Washington, D.C. 20402

4. The "Recommended Standards for Water Works" Great Lakes - Upper Mississippi River Board of State Sanitary Engineers, can be obtained for $1.00 per copy from:

   Health Education Service
   New York State Dept. of Health
   P.O. Box 7283
   Albany, New York 12224

5. Listing of Publishers:

Publisher	Address
Academic Press, Inc.	111 Fifth St., New York, New York 10003
American Chemical Society	1155 Sixteenth St., N.W., Washington, D.C. 20036
American Institute of Chemical Engrs.	36 E. 47th St., New York, New York

Publisher	Address
American Society of Civil Engineers	345 E. 47th Street, New York, New York 10017
American Society of Mechanical Engrs.	345 E. 47th Street, New York, New York 10017
American Society of Testing Materials	1916 Race St., Philadelphia, Penn. 19103
Ann Arbor Science Publishers, Inc.	P.O. Box 1425, Ann Arbor, Michigan 48106
Cast Iron Pipe Research Assoc.	Executive Plaza East, 1211 W. 22nd St., Oak Brook, Illinois 60521
Chemical Engineering Magazine	330 W. 42nd St., New York, New York 10036
Chemical Publishing Co., Inc.	212 Fifth Ave., New York, New York 10003
Chlorine Institute, Inc.	342 Madison Ave., New York, New York 10017
Interscience Publishers, Div. of J. Wiley & Sons	605 Third Ave., New York, New York 10016
John Wiley & Sons	605 Third Ave., New York, New York 10016
McGraw-Hill Book Company, Inc.	330 West 42nd St., New York, New York 10036
National Academy of Sciences	2101 Constitution Ave., Washington, D.C. 20418
National Lime Assoc.	925 Fifteenth St., N.W., Washington, D.C. 20005
Oxford University Press	200 Madison Ave., New York, New York 10016
Pegasus Press	350 Third Ave., New York, New York 10022
Pergamon Press, Inc.	4401 21st St., Long Island City, N.Y. 11101
Plenum Press	227 W. 17th St., New York, New York 10011
Prentice-Hall, Inc.	Englewood Cliffs, New Jersey 07632
Van Nostrand Reinhold Company	450 West 33rd St., New York, New York 10001
Water Pollution Control Federation	3900 Wisconsin Ave., Washington, D.C. 20016
World Health Organization	The United Nations, New York, New York